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JUN 27 1941

VOL. II. No. 4 APRIL 1941

THE ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

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Published by Engineers' Digest Ltd., 120, Wigmore Street, London, W.1
Distribution: E. & F. N. Spon, Ltd., 57, Haymarket, London, S.W.1
Price £2 2 0 per year

THE ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

Published Monthly at 120, Wigmore Street, London, W.1

Publishers: **ENGINEERS' DIGEST LTD.** - - - Telephone: WELBECK 9357

Advertisement Dept. - 120, Wigmore Street, London, W.1
Telephone: Welbeck 9357

Distribution - - E. & F. N. SPON, LTD., 57, Haymarket, London, S.W.1
Telephone: Whitehall 1860. Telegrams: Fenspon, Lesquare, London

Editorial Dept. - - 120, Wigmore Street, London, W.1
Telephone: Welbeck 9357

Subscriptions to: ENGINEERS' DIGEST LTD., 120, Wigmore Street, London, W.1, or E. & F. N. SPON, LTD., 57, Haymarket, London, S.W.1

Annual Subscription of 12 numbers, £2 2s. Single Copies, 4/6

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EXPERIMENTS ON SCAVENGING SYSTEMS OF TWO-STROKE PETROL INJECTION ENGINES WITH SPARK IGNITION

By Dr. Ing. Hold. (From " MTZ," *Motortechnische Zeitschrift*, Vol. 2, No. 11, November, 1940, pp. 347-354).

A knowledge of the influence of a particular scavenging system on the power output and fuel consumption of an engine is essential in view of the recent development in aircraft engines. Measurements of this nature obtained so far do not give, however, comparable figures for the different scavenging systems. In the following, three already known scavenging systems will be investigated, their design being somewhat simplified so that they can be used with the same engine. Their efficiency is determined, and a comparison is made between the three systems.

A diaphragm was used to measure the volume of air V_r delivered by the blower. A surge tank was fixed between diaphragm and blower to ensure a uniform flow of air. The results were checked by analysing the exhaust gas-air mixture collected in the exhaust tube. By estimating the CO_2 content and metering the fuel supplied, V_r can be determined; since it is immaterial whether the whole of the air takes part in the combustion or only a portion of it, as in the case with two-stroke engines, where a portion of the air supplied by the blower passes through the cylinder during the scavenging period.

V_r and V_a, the actual fresh air charge in the cylinder after scavenging and available for the combustion, are expressed either as n cu.m./h (reduced to 1 atm. pressure and 10° C. temperature), or else as a ratio η, where $\eta = V_a/V_c$, V_c being the volume of the cylinder after the closing of the exhaust and inlet ports.

The scavenging efficiency α is given by the ratio V_a/V_r.

In the following R denotes the residue of burnt gases in the cylinder after scavenging, CO_2' the proportion of CO_2 in the cylinder before combustion, and CO_2'' the proportion of CO_2 after combustion. If now the residue R in the cylinder is considered to be separated from the fresh air charge, the amount of fuel injected must be such that after combustion the CO_2 content will increase from CO_2' to CO_2'' in order that the final CO_2 content in the exhaust gas shall be CO_2''. Hence from the value of CO_2'' and the fuel consumption, V_a can be calculated. R may be expressed in terms of η_s, where

$$\eta_s = \frac{V_a}{V_a+R} = \frac{V_c - R}{V_c}$$

and hence the proportion of the residue gas in the cylinder, or R/V_c, is given by $1-\eta_s$. η_s can also be written as $\eta_s = 1-CO_2'/CO_2''$.

The gas sample for the analysis was taken from the cylinder at about 30° before I.D.C., through a valve which is hydraulically operated. The oil pressure acts through a hole on the valve needle, and lifts this against the spring pressure. When the needle is lifted from its seat, gas from the cylinder can enter a small container. Alternatively a pressure gauge can be fitted to the valve to measure the pressure p_s in the cylinder. To measure the duration and instant of valve opening a glim lamp is fitted to a disc, which rotates with the engine shaft. The circuit to the lamp is controlled by the needle, and is closed while the needle is lifted from its seat.

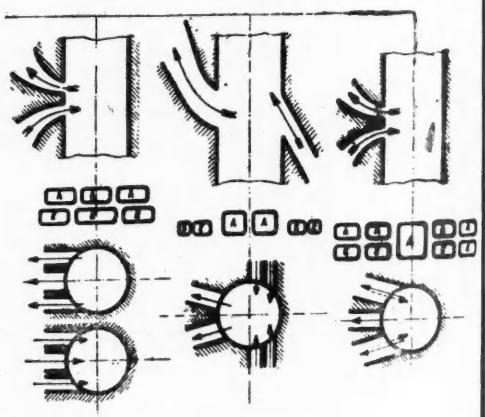


Fig. 1

A transparent graduated disc is placed in front of the lamp. Finally the temperature in the cylinder t_s before combustion can be calculated, since p_s, V_a, R, and V_c are all known.

The engine used for the experiment was a two-stroke, two-cylinder engine, with 160 mm. bore, 260 mm. stroke, and the speed was 500 r.p.m. The three scavenging systems investigated are shown in Fig. 1. "B" represents a standard arrangement; "F" is a modification of "B," such, that the exhaust ports are brought down in line with the lower edge of the inlet ports; "A" has inlet and exhaust ports almost perpendicular to each other.

In Fig. 2 the cross sectional areas of the inlet ports f_c, outlet ports f_a, and of a reduced opening f_r, replacing f_a and f_c, are plotted against the crank shaft position. The coefficients of flow calculated from the values of f_r, pressure and volume were found to be

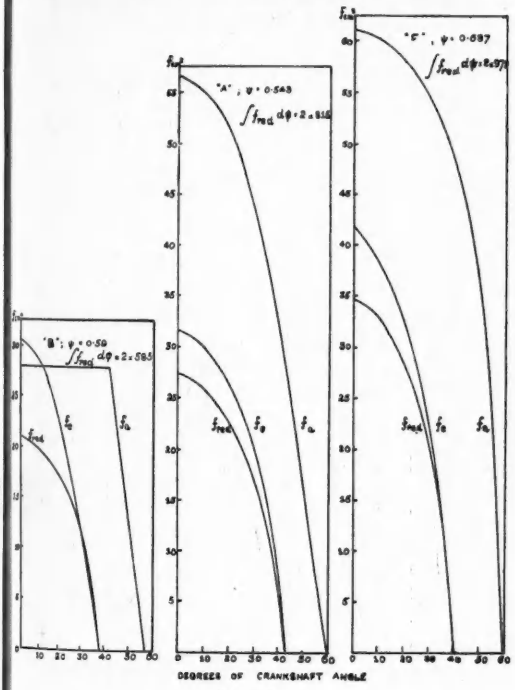


Fig. 2

0.59, 0.543 and 0.687 for "B," "A," and "F" respectively. In other words, the resistance to flow is the smallest in case of "F" and is the largest in case of "A." "B" was also examined with ports equal to that of "F" or "A," but no improvement was obtained; on the other hand conditions became worse when f_r in case of "F" was made equal to that of "B."

Fig. 3 shows the specific fuel consumption of the engine with the three scavenging systems. Also the blower boost in kg/cm² can be seen from Fig. 3.

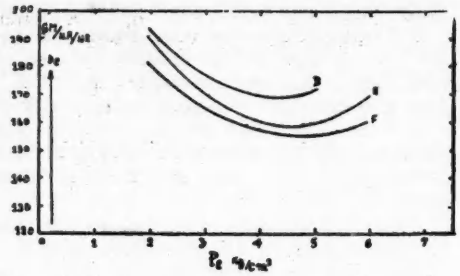
In Fig. 4 the quantity of excess air λ and the specific consumption is shown. Since from the values of λ it can be seen that these lie between 1.24 and 1.36, the load at $\lambda = 1.3$ was selected as limiting load.

Scavenging Arrangement	"B"	"A"	"F"
Air Supplied L ..	0.945	1.043	1.123
Scavenging pressure in mm.Hg	178	133	68
Flow Efficiency ..	0.59	0.54	0.69
Blower boost kg/cm² ..	0.40	0.33	0.17

The differences in the fuel consumption and output of the engine after allowing for the power taken by the blower, should be attributed to the scavenging system.

The CO_2 content immediately outside the exhaust port is shown in Fig. 5. On the exhaust port being uncovered the CO_2 content rises rapidly until it reaches a maximum value, obviously equal to that in the cylinder after combustion. This is followed by a decrease, due to the scavenge air flowing through the cylinder into the exhaust pipe. In case of "A" and "F" the fresh air escapes to the exhaust system almost at once, i.e., the air flow is "short circuited." The cylinder is filled relatively slowly with fresh air, and hence the CO_2 content increases again in the exhaust pipe. It seems that the scavenge air thus pushes the burnt products in front and does not mix with them. As scavenging proceeds the CO_2 content diminishes again. The results are slightly modified in case of "B," because there is no "short circuit" in the air flow.

It can be seen in Fig. 6 that the first pressure wave causes the inevitable rise in the temperature, followed by a fall in temperature owing to the "short circuit," finally a

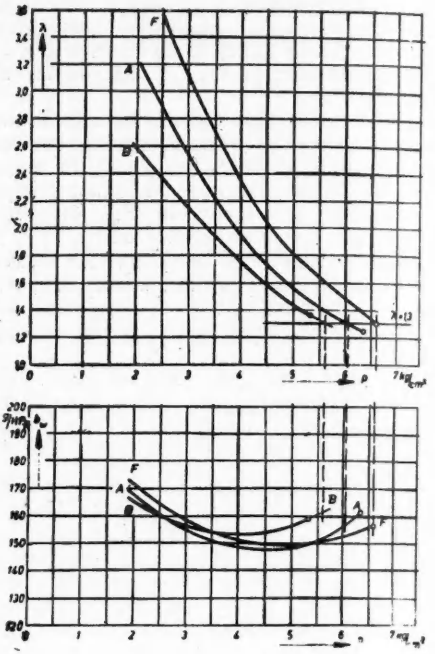


Figs. 3 and 4

second temperature peak is obtained as scavenging proceeds.

The pressure variation in the cylinder can be seen very clearly from Fig. 7, in case of "B." When the exhaust port is uncovered the pressure falls below the scavenging pressure then rises until about the O.D.C. is reached, it remains constant for a short period, and falls again as the piston speed is increased, finally rises again when the piston is about to close the ports.

The lower part of the Fig. 7 shows the pressure variations in the surge tank. The broken line indicating the pressure variation,



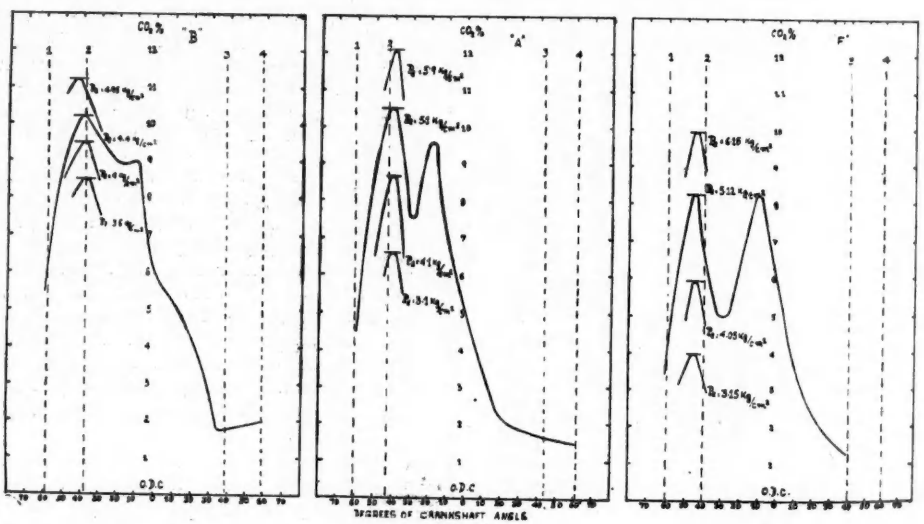


Fig. 5

(1) Exhaust port opens; (2) Inlet port opens; (3) Inlet port closed; (4) Exhaust port closed.

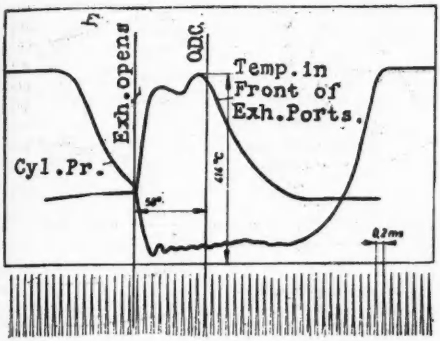


Fig. 6

when the volume of the container was reduced from 48.1 to 30.1.

Fig. 8 shows variations of various characteristics discussed above.

Comparing the results of "A" and "F" it can be seen that the specific fuel consumption figures differ only slightly, and at $\lambda = 1.3$ they are almost identical. At the same time the values of V_a are 101 m^3/h and 78 m^3/h. Two factors account for the fact that with the same amount of excess air and same fuel consumption the outputs are not in the ratio of the corresponding values of V_a, namely (1) higher mechanical efficiency with higher power output in case of "F"; and (2) the specific consumption was measured for both cylinders, while V_a was only determined for one cylinder, and it was found that there is a difference in the value of V_a for the two cylinders.

The question is what accounts for the higher value of V_a obtained with "F." It can be seen from Fig. 7 that the pressure p is 19 mm. Hg. and 80 mm. Hg. for "F" and "A" respectively. The temperature t_s must differ accordingly, since the same cylinder was employed for both systems. Actually it was found that there is a considerable difference in the temperatures, t_s being (although not for the same loading) 67 and 168° C. respectively. This means that although more air is passing through the cylinder in case of "A," the heat dissipation is much superior in case of "F."

It can also be seen from the values of which is 0.88—0.92 and 0.89—0.91 in case of "F" and "A" respectively, that a high scavenging efficiency does not mean a high fresh air charge in the cylinder. Also as a consequence the value of CO_2 is higher in case of "A" than in case of "F."

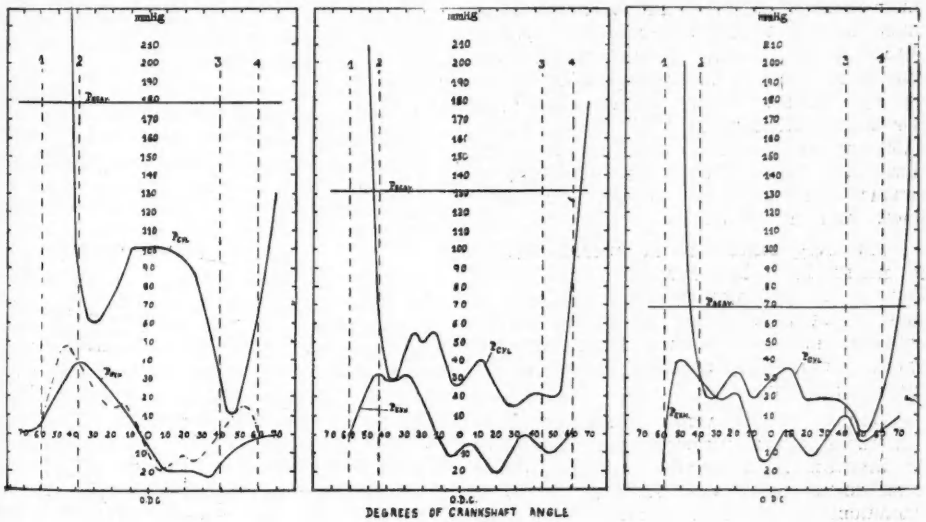


Fig. 7

(1) Exhaust port opens; (2) Inlet port opens; (3) Inlet port closed; (4) Exhaust port closed.

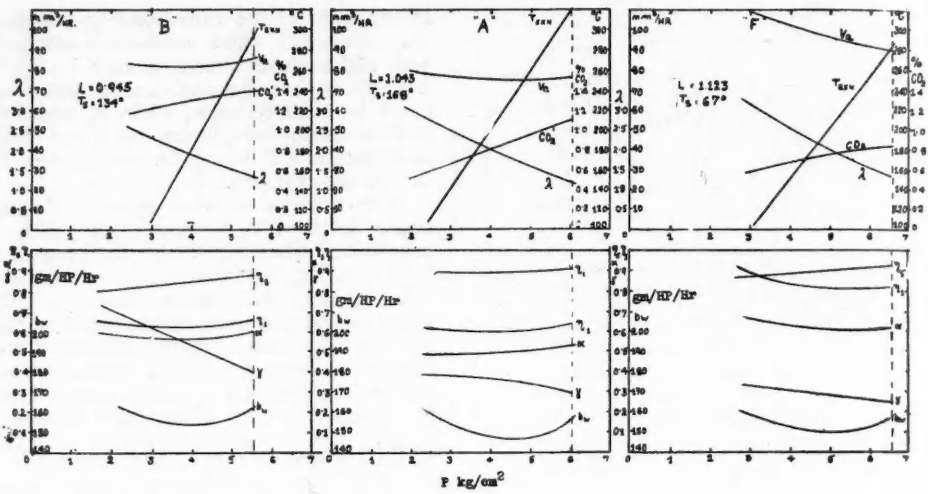


Fig. 8

On comparing "B" with "A" and "F" the following can be concluded (Fig. 11). "B" has a higher specific fuel consumption figure, and the power output is lower at the same time. Since fresh air charge is slightly more than with "A," the smaller output must be due to the inefficient combustion. Again with 1.3 the power outputs are not in the ratio of the corresponding values of V_a. Further it can be noted that the scavenging efficiency for "B" is only 0.81—0.88, but the total fresh air charge is higher than with "A." This can be attributed to smaller value of p and the correspondingly lower value of t_s (Fig. 7).

The CO_2 content in the cylinder (CO_2) is higher for "B" than for "A," partly because of the lower efficiency resulting in more residual gas being left behind in the cylinder, and partly because the residual gas contains more CO_2, as there is less dilution by the excess air.

Similar results were obtained with a scavenging system purposely made inefficient by throttling the air supply. For this purpose sheet mettal plates were fixed in the ports, conditions being otherwise identic alto a normal "A" type (Fig. 9). The air supply was

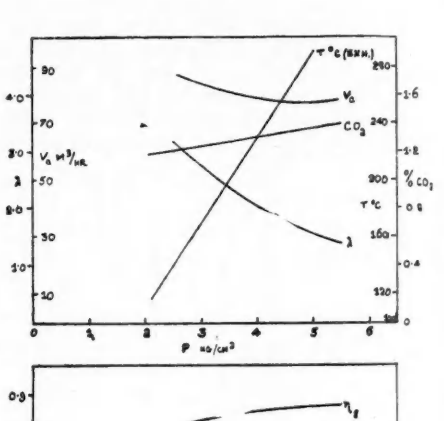


Fig. 9

kept almost at the same value, 1.01, but due to the reduced cross sectional area, greater resistance of flow was observed and the pressure was increased to 208 mm. Hg, compared with 133 mm. Hg. with the ordinary "A" type.

The specific fuel consumption showed a considerable increase throughout the entire range of loading. The value of α has diminished to 0.8—0.86. On the other hand fresh air charge did not diminish not even by an amount which would correspond to the reduced scavenging efficiency. It is interesting to note that with an inefficient system it was still possible to obtain the same amount of excess air as with a normal system.

Finally, the effect of modifications to the injection arrangements, e.g., altering the fuel injection system, on the scavenging was examined. A smaller injector was employed, the period of injection and the instant of starting the injection were altered. Although the fuel consumption increased in these cases, the scavenging efficiency and the value of V_a remained unaltered, showing that measurements of scavenging efficiency and its effect on the output and power of the engine were independent of other factors.

THE EFFICIENCY OF LIGHT A.A. GUNS

By CAPT. BAASCH. (From *Flugwehr und Technik*, Vol. 3, No. 1, January, 1941, pp. 14-18).

SINCE the great war in 1914-18 a series of light A.A. guns have been developed in different countries, with calibres varying from 7.5 mm. to 40 mm. A common feature in these guns is the firing method, since a full hit must be scored to destroy the aircraft.

For comparison the guns can be classified into four groups, namely:

machine guns up to 7.5 mm. calibre
machine guns from 12 to 14 mm. calibre
automatic guns from 20 to 25 mm. calibre and
automatic guns from 34 to 40 mm. calibre.

For comparing the suitability of guns the most important factor is the range characteristic of the gun. This follows from the general task of the guns for destroying aircraft cruising at a certain height (above 1000 m.), or fighting aircraft flying a few hundred meters high at a certain speed. The sighting device, firing rapidity, etc., are of secondary importance from this point of view.

The upper limit of the suitability of a gun is fixed by the maximum effective range of firing of the gun, and the lower limit is determined by the flexibility of the gun, i.e., the ability to follow the course of the aircraft.

It should be noted that owing to the relatively small size of aircraft, the maximum effective range of a gun is not identical with the maximum distance to which the shell can be fired, since dispersion at the maximum distances would practically nullify the accuracy of the sighting devices.

The vitally vulnerable parts of a modern aircraft at the max. efficient range of a normal machine gun amounts to about 1m² (continu-

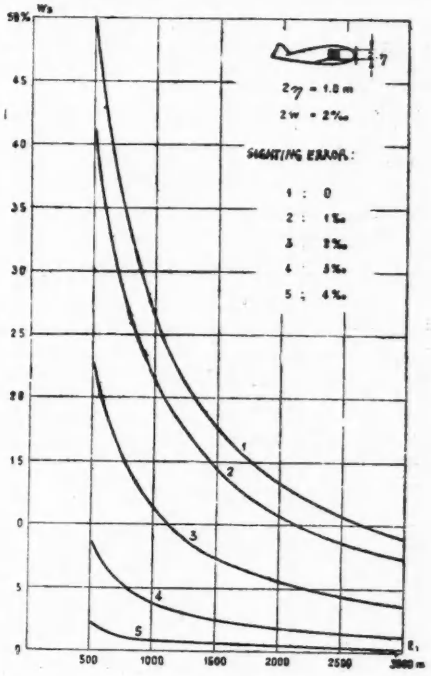


Fig. 1

ous surface). If we consider the usual firing method, i.e., short bursts at intervals with fixed sighting elements, then the calculation of the probability of hitting is fairly simple. A graph showing the probability of hitting for various sighting errors is shown in Fig. 1. (Compare with *Engineer's Digest*, Vol. 1, No. 6, pp. 200 and 201, and note: 2w is the dispersion of projectiles).

It can be seen that with a probability of hitting of 15% and with a sighting error of 2‰, the maximum effective range of a normal machine gun of about 7.5 mm. calibre is 750 m. This figure agrees with that found in practice.

With increasing calibres the size of the vitally vulnerable part is also increasing. In the following table the surface area (continuous) of the vulnerable part is tabulated for the four A.A. gun groups.

Calibre	Vitally vulnerable surface
7.5 mm.	1 m².
12-14.0 mm.	1.8 m².
20-25.0 mm.	4.0 m².
34-40.0 mm.	7.0 m².

In Fig. 2 the probability of hitting is plotted corresponding to these surface areas, but only

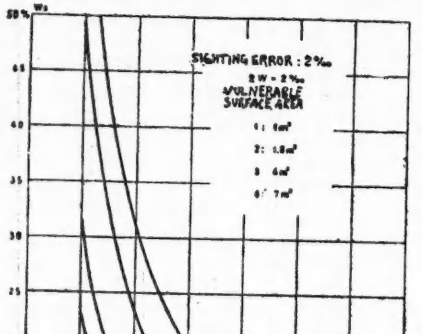


Fig. 2

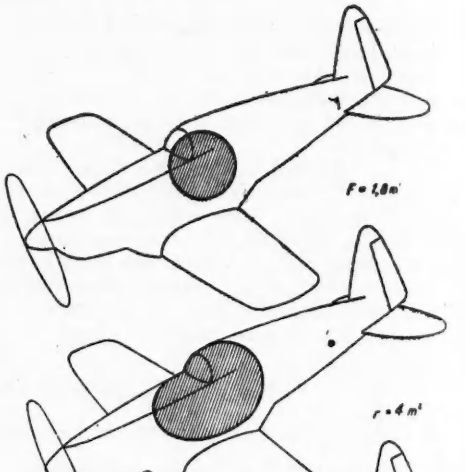


Fig. 3

for a sighting error of 2‰. Assuming again a 15% probability of hitting, we can read off the following values for the maximum effective ranges for the different calibres:

Calibre	Max. eff. range
12 to 14 mm.	980 m.
20 to 25 mm.	1500 m.
34 to 40 mm.	1950 m.

So far the time of shell travel and the consequent lead of sighting, which has a considerable influence on the probability of hitting was not taken into account. As an example the time taken by a shell to travel the first 750 meters (initial velocity 825 m/sec. for all types of guns) is:

Calibre	Time in sec.
7.5 mm.	1.2
12 to 14 mm.	1.1
20 to 25 mm.	1.1
34 to 40 mm.	1.0

This means in other words that the reduction of time of bullet travel is for guns of 12 to 25 mm. calibre 1.1 times that of a 7.5 mm. gun and 1.2 times that of a 7.5 mm. gun for 34 to 40 mm. calibre guns.

According to Rougeron the efficiency of A.A. guns is inversely proportional to the cube of the time of shell travel. If we assume this to be correct then the practical limits of effective ranges for guns having larger calibres can be read off the graph 2 at values of 15% times the factor of 1.1^3, 1.2^3 respectively. The practical limits of the effective maximum range become thus :

Calibre	Practical limits of range
7.5 mm.	750 m.
12 to 14 mm.	1300 m.
20 to 25 mm.	2000 m.
34 to 40 mm.	3500 m.

The above results are based on similar errors of sighting and gun characteristics for the various calibres. In practice, however, these conditions are not fulfilled. To compare, therefore, existing models, many other factors as well must be considered, such as the optimum accuracy of sighting, quickness of firing, etc.

Summarising the results it can be seen that guns with larger calibre have an advantage over smaller guns, mainly owing to the fact that the accuracy of sighting has a very marked influence upon the probability of hitting. On the other hand the features in favour of lighter guns are : greater rapidity of firing, higher initial velocity of the bullet. It should be borne in mind, however, that all these factors are governed by economical considerations and could be altered if the proportion of cost of gun/cost of sighting device would be altered.

Fig. 4

A few more words should be said about the vulnerability of the modern aircraft. It can be stated already at this stage of the war that the vulnerability of the aircraft is diminishing with improved protection. Fig. 4 shows a German aircraft, severely damaged by the British ground defences, which is claimed to have reached its base with the aid of the second engine. A definite race is existing between the improvement of aircraft protection and the efficiency of A.A. guns. At the same time, many an aircraft has been destroyed by guns of the smallest calibre.

TORSIONMETERS FOR AERO ENGINES IN FLIGHT

By K. A. LÜRENBAUM. (From *Zeitschrift des V.D.I., Berlin*, March, 1940).

To obtain a true idea of the performance of an aero engine, it is essential to measure the power supplied to the air-screw, when in flight. Registration of the indicated power is no criterion as it disregards the mechanical efficiency of the unit. The power must be determined at the air-screw itself.

Since the transmission of power involves two measurable quantities, viz., speed and torque, an instrument is necessary to record the torque. This has been achieved very simply in practice by measurement of the axial distortion of the transmitting shaft. From the fundamental formula $T = \frac{c.\ \theta\ .J}{l}$ $= k\ \theta$, the relative movement between two

sections of the shaft gives a direct indication of the torque.

For aero engine application the following has to be observed in the construction of a suitable indicator of torsion.

(1) The instrument should withstand vibration, change of temperature, and centrifugal force.

(2) It must be simple to obviate the inherent inaccuracies attendant with mechanical complication.

(3) The apparatus should be compact.

(4) Inertia effects should be absent.

(5) The instrument should be sensitive over the whole speed range.

(6) Service safety up to 6000 r.p.m.

In the first instance it was intended to develop an instrument to measure torsional vibration in the reduction gear of the air-screw. An incidental result was a continuous recording of the torque transmitted to the air-screw. The instrument finally evolved, shown in Fig. 1, is essentially made up from two parts. A rigid elongated collar (a) in two halves, concentric with the transmission shaft, and clamped at one end. This tube follows strictly the rotational movement of the shaft at the clamping plane as it transmits no power. The tube is arranged to carry a light stylus (g), and the slip rings(1) of the electrically operated time and revolution marking mechanism. The pressure exerted by the stylus is not influenced by variation in the speed of the air-screw. A collar (b) is clamped to the shaft so that it bears close to the tube. This collar follows the rotational movement of the shaft at the clamping plane, and therefore, when the shaft is transmitting power, there occurs a relative movement between the two collars. This movement is recorded without magnification. on a film carried by the collar.

In operation the film (f) is wound round a pinion (d) carried by the collar (a) and which engages with a worm wheel (c) riding loose on the shaft. The worm wheel is fitted with a brake which may be operated by the observer. When the brake is applied relative movement between the worm and collar causes the pinion to rotate, thus the film is drawn over the stylus carried by the collar (a), and a continuous recording of the relative displacement of the two collars (a) and (b) is obtained. When the brake is released the worm rotates with the shaft and movement of the film ceases. A spring is provided to hold the brake off the worm. Time and revolution indications are put on the film by an electro-magnetic device. A datum line is impressed on the film by a stylus fixed to the collar b. As no magnification of the movement is provided, the main difficulty was in the actual recording of the movement.

Finally the impression given by a diamond

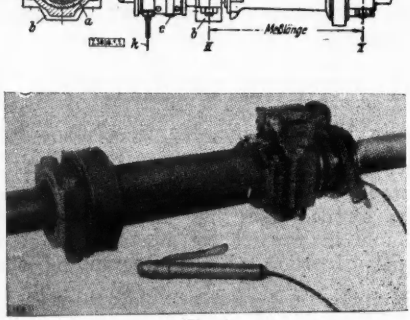


Fig. 1
(Messlänge=Working length.)

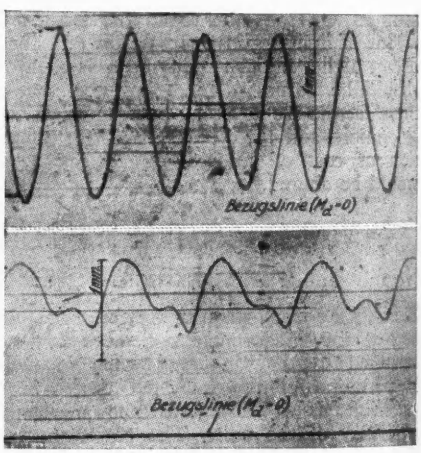


Fig. 2
Typical Torsiographs. (Bezugslinie=Reference line)

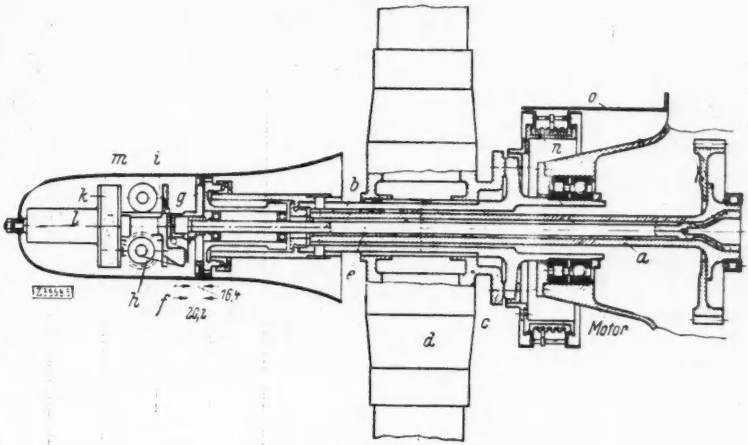


Fig. 3

Section through the Torsionmeter.

(a) Driving shaft; (b) Hollow shaft; (c) Air-screw hub flange; (d) Air-screw; (e) Actuating bar; (f) Stylus; (h and i) Film bobbin; (k) Film unrolling mechanism; (l) Electric motor; (m) Streamlined nose; (n) Timing mechanism.

point carried by the stylus was improved. After many experiments a line thickness of 0.01 to 0.005 mm. was reached. This line was sufficiently thin to give an accurate copy of the relative displacement of the two parts of the *torsionmeter*.

Fig. 2 shows some of the diagrams to an enlarged scale. The reference line can be clearly seen.

The foregoing was a description of the *torsionmeter* as first developed. For the actual measurement of the power absorbed by the air-screw, the instrument is slightly modified and its construction may be seen from Fig. 3. The power is transmitted through the reduction gear to the shaft (a) passing through a hollow concentric shaft (b) which carries the air-screw (d). The two shafts are keyed to-

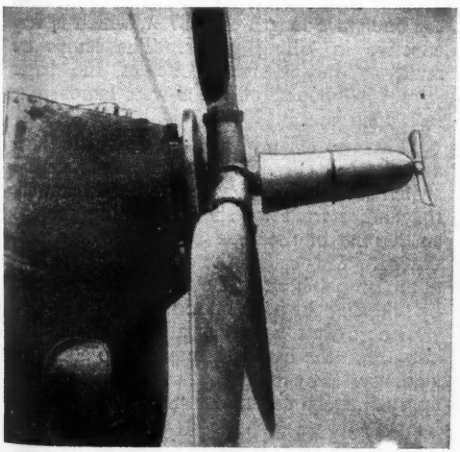


Fig. 4

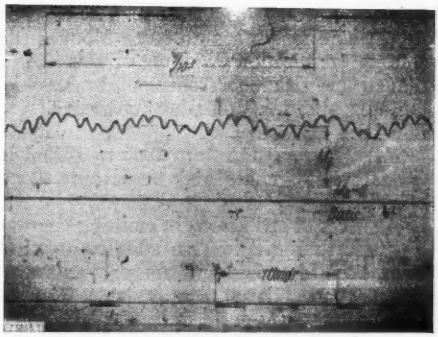


Fig. 5

Torsiograph obtained with the instrument shown in Fig. 3.

gether at one end. The inner power shaft is adapted to operate the *torsionmeter*. A rigid shaft (e) passes inside the power shaft (a) and is keyed to it at the far end. The recording apparatus is fitted to the other end of the power shaft so that the distortion of the length of shafting (a) is registered on the film by the stylus (f) carried by the actuating rod (e). The power to unwind the film is supplied either by a small electric motor (1) as Fig. 3, or by a small pilot air-screw as in Fig. 4. A suitable disengaging mechanism is provided so that when the instrument is not in use vibration will not cause the stylus to perforate the film.

An interesting comparison between the laboratory dynamometer method and the torsionmeter method of indicating the power delivered by an aero engine is provided by the graph in Fig. 6.

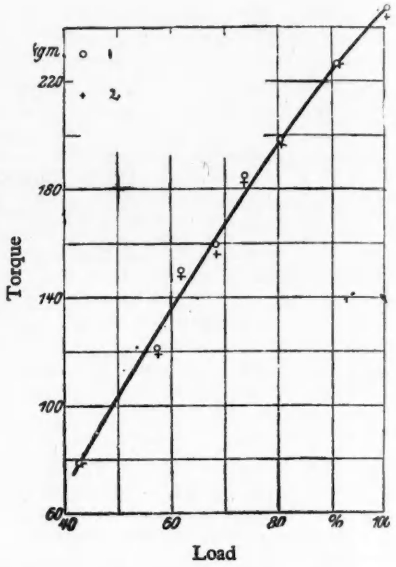


Fig. 6

(1) Torque on the water brake; (2) Torque shown on the Torsionmeter.

GERMICIDAL LAMPS—A NEW TOOL FOR INDUSTRY AND A CONTRIBUTION TO HEALTH

By L. C. PORTER and P. W. NEIDHARDT, General Electric Company, Nela Park, Ohio.
(From *General Electric Review*, Vol. 43, No. 5, May, 1940, pp. 202-205).

ULTRAVIOLET radiation covers the range from approximately 1800 Å units (λ) wave length to 4000 λ. This part of the spectrum may be divided into four ranges approximately:

(1) The radiation up to 2000 λ characterised by production of ozone.

(2) The range from 2000 to 28000 λ suitable for sterilization or killing of bacteria.

(3) The radiation from 2800 to 3200 λ is building up bones and teeth (creation of vitamin D).

(4) The radiation from 2800 to 3200 λ has special photographic and fluorescent display effects.

Sources of artificial light emitting energy of all these four divisions in addition to visible light, such as carbon and iron arcs and quartz mercury arcs, have been available for many years. But they were rather costly and of relatively high wattage.

The new germicidal lamps are available in 3-, 5-, and 15-watt sizes (Fig. 1.). Operating voltage is 110-125 volts. Approximately 95% of their ultraviolet output is confined to the one wave length of 2537 λ, which is very effective in killing germs. The lamps are relatively inexpensive. (Life of the larger sizes 1500 hours, of the 3-watt lamps more than 1000 hours).

The 3-watt lamp works in connection with a choke coil (Fig. 2). An automatic starting switch is under development. Meanwhile they are started by short-circuiting the two small pins in the base by means of a push button. This causes the cathodes in each end of the lamp to heat. The circuit is then opened by releasing the push button.

The 5-watt lamp has a self-contained resistance in the base and requires no additional auxiliary. But the output of this lamp is only approximately one-fourth that of the 3-watt lamp.

The 15-watt lamp is identical with the 18 in. fluorescent tube, extensively used for

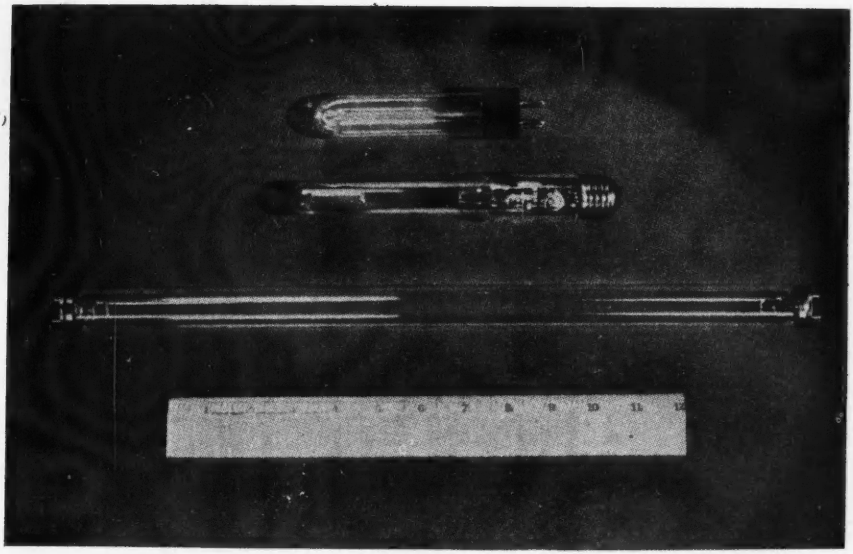


Fig. 1
The 3-, 5-, and 15-watt sizes of germicidal lamps.

lighting purposes, except that it is made of a special high-transmission glass and has no phosphor on the inside of the tube. These lamps are equipped with an automatic starting switch, and most of them use aluminium reflectors. Aluminium must be used for these reflectors, as most other materials, except chromium, reflect very little ultraviolet radiation.

It has been stated in the Research Laboratory of the General Electric Company that a bare 15-watt lamp will kill B-Coli, the organism widely used to test effectiveness of germicidal agents, at a distance of one meter in 30 sec. It has been determined that the lethal dosage for B-Coli on the surface of moist agar jelly is approximately 6600 micro-watt-seconds per square centimeter, while B-Coli in air at ordinary room temperatures and humidity are killed by approximately 1500 micro-watt-seconds per square centimeter. The output of a 15-watt lamp is 20-25 m.w. per cm^2 at one meter distance, that of the 5-watt lamp 1 m.w., and that of the 3-watt lamp 3-4 m.w. A single 15-watt lamp in a nonreflecting air duct will kill approximately 97% of all B-Coli in the air passing through the duct at a rate of 200

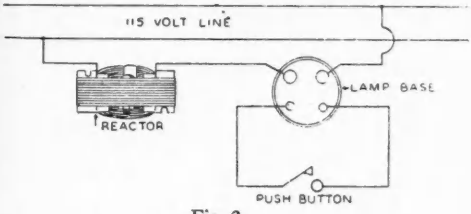


Fig. 2.
Connection diagram for the 3-watt lamp, showing reactor and controlling push button.

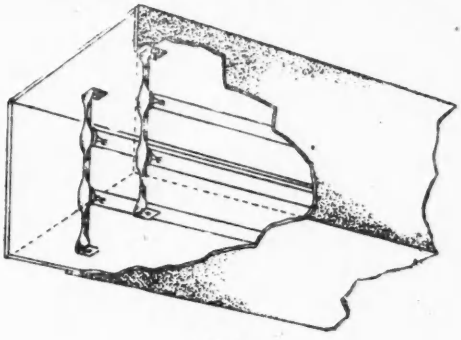


Fig. 3.
Sketch showing method of installation of germicidal lamps in an air duct for sterilizing the air in an air-conditioning system.

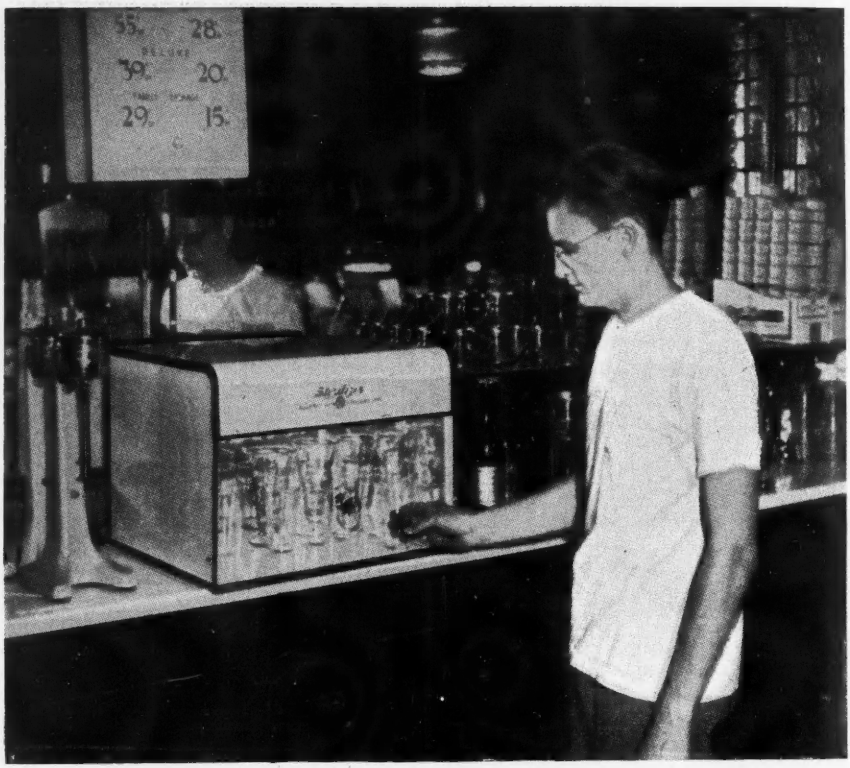


Fig. 4.
A drug-store cabinet equipped with germicidal lamp for sterilizing beverage glasses.

cu. ft. per min. If the duct is lined with aluminium to reflect the ultraviolet, considerable greater volumes of air can be handled by a single lamp.

As ultraviolet radiation follows approximately the same laws as visible light, it can be concentrated by suitable reflectors. One 3-watt lamp fitted with a parabolic aluminium reflector produced an intensity of approximately 1500 micro-watts per square centimeter at a distance of 6 inches from the reflector. At that point B-Coli in air would be killed in one second.

The lamps are being used successfully for sterilizing air in the ducts of air-conditioning equipments (Fig. 3), for the prevention of the formation of mould in food industries such as walk-in coolers, refrigerated display cases, domestic refrigerators, bakeries, dairies, etc. They are particularly well suited for use in cabinets to kill germs on soda water glasses, dishes and eating utensils (Fig. 4), and to maintain surgical and dental instruments and barbers' tools in sterile condition. Wide use, of course, can be made of these lamps in hospitals. In four hospitals a narrow sheet of germicidal radiation has been provided across doors or other open entrances to rooms (Fig. 5). Such ultraviolet barriers destroy air-borne germs passing through the barriers.

Care must be taken that ultraviolet radiation may not fall directly into the eyes, as it may cause severe cases of conjunctivitis. The lamps have to be fixed suitably, or the eyes

protected by goggles or eye-glasses. Ordinary eye-glasses afford adequate protection, as 2537 λ radiation will not pass through ordinary glass.

The construction of many articles makes it difficult to reach all parts of them with direct or reflected radiation. For some purposes, therefore, it may be better to continue conventional methods of sterilization and then maintain the article in a sterile condition by keeping it under the radiation of germicidal lamps.

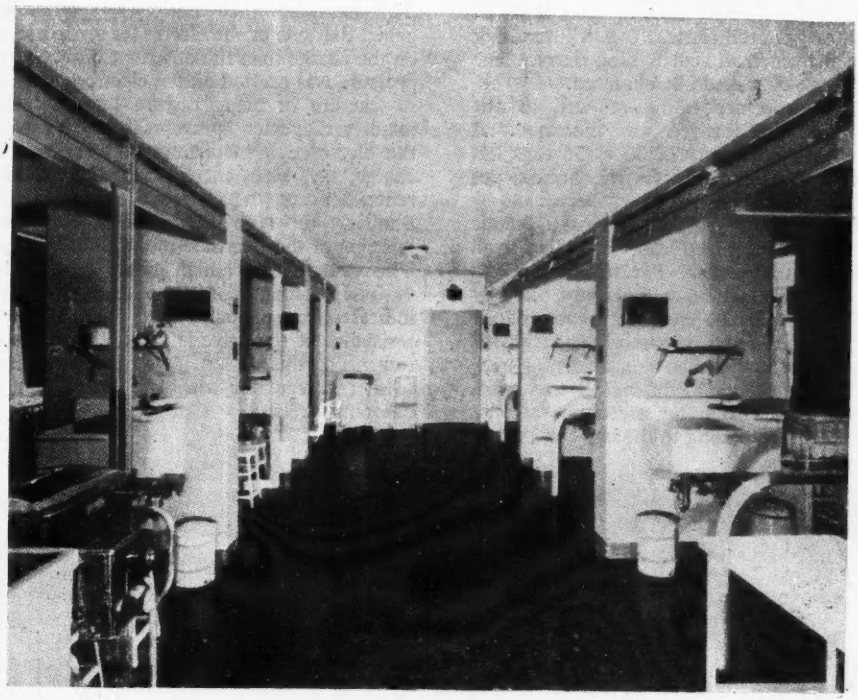


Fig. 5.

Germicidal lamps provide a sterilizing screen in the entrances to these hospital babies' cubicles.

PRACTICAL RESULTS WITH ULTRA-VIOLET RADIATION

(From an abstract from *Pressedienst Reichsbahn*, April, 1940, in "*Bulletin of Association des Electriciens Suisse*," Vol. 32, No. 1, January 15th, 1941, p. 11).

A RADIATION plant was installed in a mine of the Krupp works in spring, 1938. A gallery, which the gang of men had to pass when leaving the pit, has been equipped with lamps radiating ultra-violet light. This experiment had very good results. An essential improvement of the blood and an increase of the blood pigment resulted after short use. Furthermore, excellent results were achieved in regard of rheumatism, bronchitis and influenza. Only 30% of the gang treated with radiation were attacked of bronchitis during 1939, against 90% of the men of a mine without a radiation plant. A similar result could be observed in regard of the epidemic of influenza in spring, 1939, when the mine with radiation plant had three times less victims than the mine without such a plant. The period of radiation, applied for one minute at the beginning and extended gradually up to seven minutes daily, was ten weeks.

NEW TYPE OF ELECTRIC FURNACE

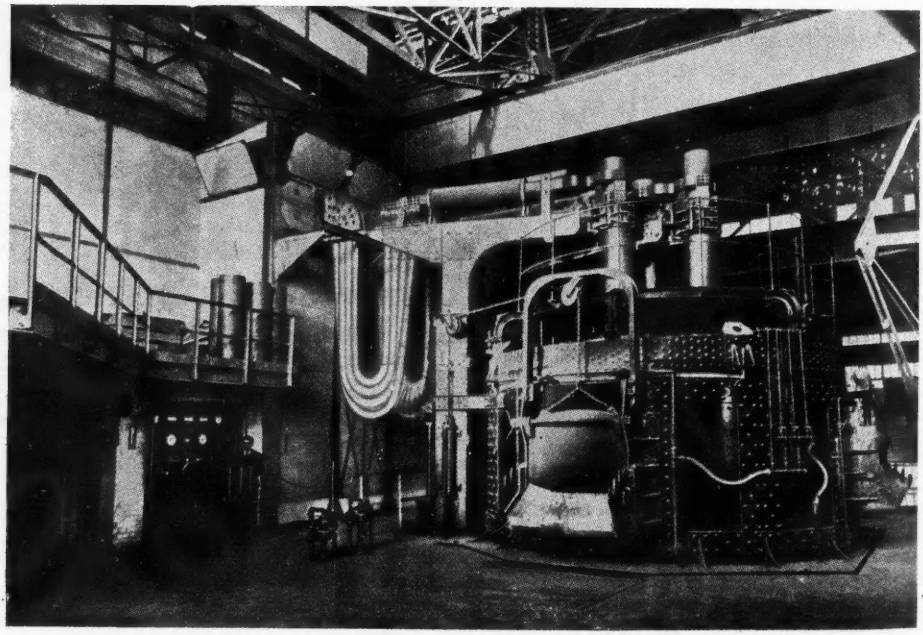
By P. FABER. (From *Brown Boveri Mitteilungen*, Vol. 28, January, 1941).

WHERE the tariff charges favoured the use of electricity, the electric furnace soon replaced the coal or gas fired furnace. It is interesting to note that even in coal mining districts the same change-over could be observed.

The transformer rating as well as the capacity of the furnace was increased. A furnace with a capacity of 30 to 36 tons has been completed recently for the Société des Aciéres de Micheville, France.

For over fifteen years the electric-hydraulic regulation of the electrodes has satisfied all practical requirements. The increase of the furnace output and more especially the ever increasing use of the electric furnace for refining S.M. and Thomas steel, and for the production of low carbon non-oxidising steel, necessitated a change in the regulation system. With the new system the electrodes are not advanced corresponding to the current, but are controlled by the resistance of the electric arc. This has several advantages. It often happened that one of the electrodes started sooner on the charge than the other. Consequently a pressure was exerted on the electrode resulting in fracture in many cases. The new wattmeter arrangement prevents this by stopping the electrode immediately on contacting the charge, i.e., when there is no potential difference between the electrode and the charge. Similarly, this type of regulation prevents submerging of the electrode into the molten mass. The regulation has a high stability.

The turning moment of the regulator is increased from about 12 kg to 40 kg, so that the resistance of the valve is negligible in proportion. For this reason it was found necessary to fit the regulator with a more effective oil-damping device.



SPIRE-TYPE SINGLE-CIRCUIT STEEL TOWERS SUPPORTING 100,000 VOLT TRANSMISSION LINE

By A. E. DAVISON, Hydro-Electric Power Commission of Ontario. (From the Bulletin "*The Hydro-Electric Power Commission of Ontario*," Vol. 27, No. 10, October, 1940, pp. 311-314.)

OPERATING experience along the Atlantic seaboard, along the Niagara river and elsewhere has indicated that greater separation of the conductors is needed than that used during the past 30 years if short-circuits and arcs to ground are to be avoided, while ice-laden conductors and ground cables are moving about in the span asynchronously as a result of the action of moderate winds upon them. Increasing the vertical clearances would seem to be the safest, although not necessarily the most economical, way of assuring service security. Increased separation between a layer of power phases and the overbuilt ground cable improves protection against lightning and against faults caused by galopping.

A new 110-kV transmission line of the Hydro-Electric Power Commission of Ontario from St. Thomas to Windsor on the Detroit River, illustrated by Figs. 1, 2 and 3, has been built with the exceptionally great vertical separation of 25 feet between the ground cable and the plane of the power cables, being about twice that used in many designs during the past thirty years. Other dimensions of the suspension towers of this line are as follows:

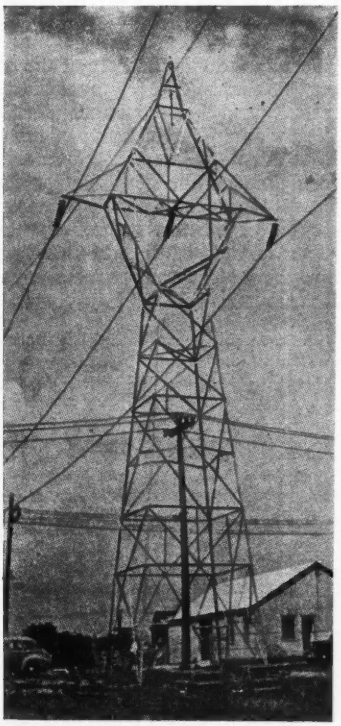


Fig. 1.
Spire-type, 110 kV, single circuit structure complete with elevated ground cable.

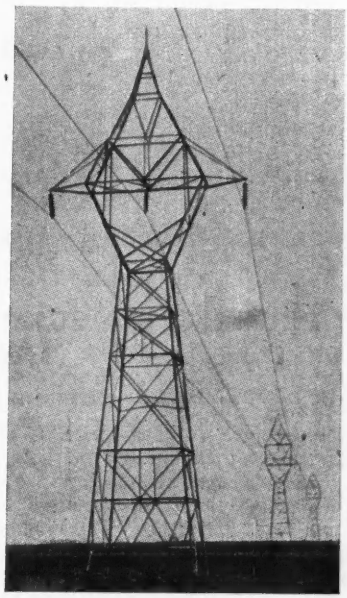
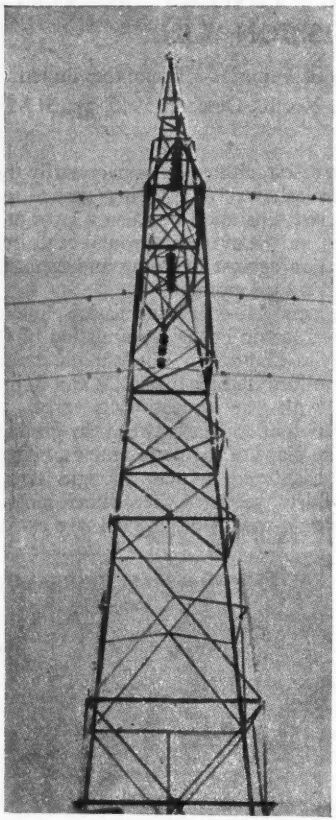


Fig. 2.
Standard and transpositional towers without ground cable.



Height of crossarm over ground 59 ft. 6 in.
Vertical separation of point of attachment of ground cable over crossarm .. .. 21 ft.
Height of the spire over point of attachment of ground cable.. .. .. .. 4 ft.
Base of tower .. .. 16×16 ft.
Horizontal separation of conductors 15 ft.
Conductors 3×477.000 circ. mils. A.C.S.R.
Ground cable 1 × $\frac{5}{16}$ in. Galv'd Steel
Normal span .. .. ..1000 ft.
Max. tangent span .. .. ..1330 ft.

Data issued by the Weather Bureau indicate that about forty lightning storms per annum may be expected in the region of the new line, which lies, if anything, along rather than across most storm paths. More orthodox types of transmission lines have operated quite successfully in this area for periods of from 26 to 30 years without either special grounding of steel towers—typically 20 Ohms, with some areas averaging 40 Ohms per tower—or counterpoise facilities. Outages of these older lines due to lightning are of the order of 0.8 per 100 circuit miles per annum. In order to study the economics and service securities of ground cables and of high speed automatic circuit breakers, a ground cable has not been used on the new line for the time being. Experience during one lightning season would indicate that ground cables are desirable additions of lines of this type even after they have been equipped with high speed circuit breakers.

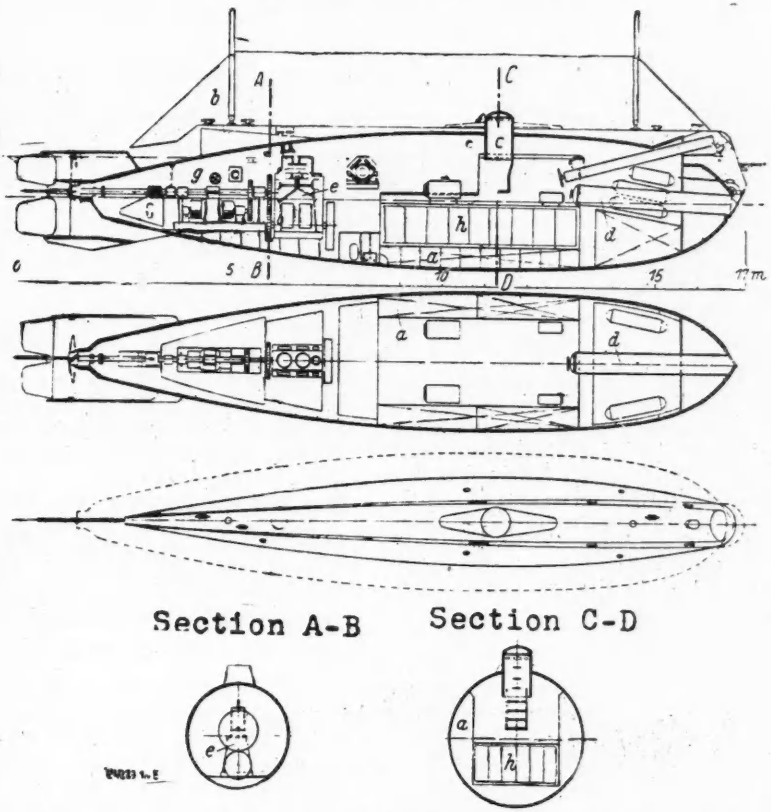
Fig. 3.
Spire-type construction (side view) without ground cable. The conductors are equipped with a new type of torsional absorbers.

PROGRESS IN SUBMARINE CONSTRUCTION BEFORE THE WORLD WAR

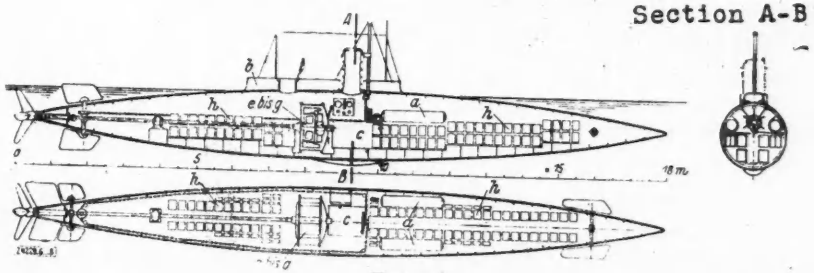
By ING. H. TECHEL. (From *Zeitschrift des V.D.I.*, Vol. 84, No. 50, November, 1940).

United States. After a series of abortive experiments carried out by the U.S. Navy, Mr. Holland launched the first successful boat (Fig. 1-5) in 1898, completed in the Holland Torpedoboat Co. The submarine of 74 tons displacement had a very suitable shape for submerged running. The armament consisted of a torpedo tube at the bow and two tubes for air torpedoes, the hull was single walled. The Congress agreed to the manufacture of six more boats of the same type in 1900. Credit should be given to Mr. S. Lake who contributed a great deal to the development of submarine construction.

France. Here the construction of the first submarine was carried out by the Navy. Already in 1886 a submarine has been completed (Figs. 6-8) by G. Zédé, having 30 tons displacement propelled by an electric motor. The power was supplied by an accumulator.



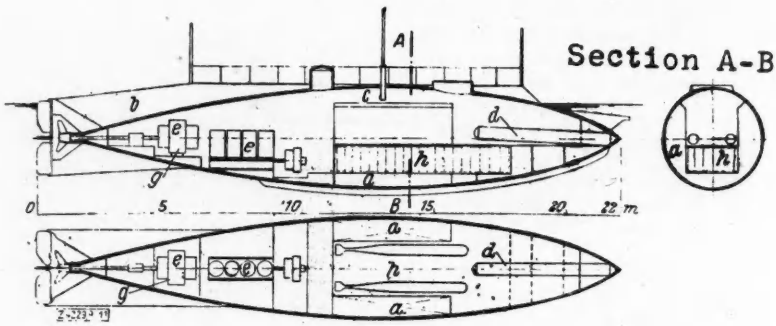
Figs. 1–5. (a) Saddle tanks; (b) Trimming tanks; (c) Conning tower; (d) Torpedo tube; (e) Surface engine; (f) Steam boiler; (g) Electric motor; (h) Electric batteries.



Figs. 6–8

The boat had no armament and according to reports it was very difficult to keep it at the desired depth.

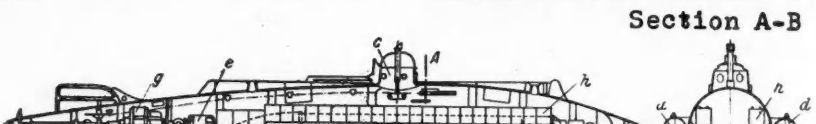
In response to a competition sponsored by the Navy in 1898, Labeuf designed a double hulled boat, the "Narval," which was driven by a steam engine on the surface, and was the first boat suitable for war purposes.



Figs. 9–11

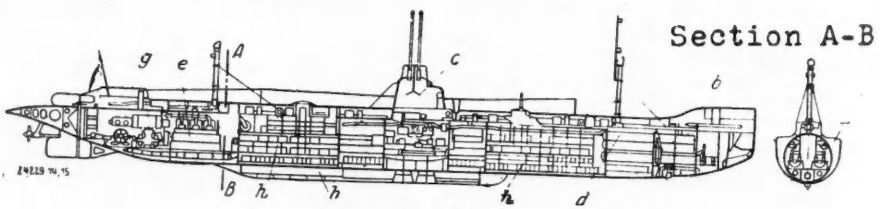
Italy. The small experimental boat, "Pullino," was finished by the Navy in 1892 (47 tons displacement), and was followed by the "Delphino" (95 tons). Both these were driven by an electric motor. But in 1901 the latter was reconstructed and equipped with an internal combustion engine for the surface propulsion. A later design, the "Glauco," a boat of 160 tons displacement was also fitted with an internal combustion engine for surface operation.

Sweden. The first submarine the "Hajen" completed by the Navy was launched in 1905, and was fitted with one torpedo tube. An I.C. engine of the spark ignition type supplied the propelling power on the surface and also drove by a generator connected to an accumulator. In 1914 the ignition engine was replaced by a Diesel engine. The fuel oil was stored in tanks. To compensate for the weight of the fuel used up, water was admitted into these tanks, keeping the oil level approximately constant.

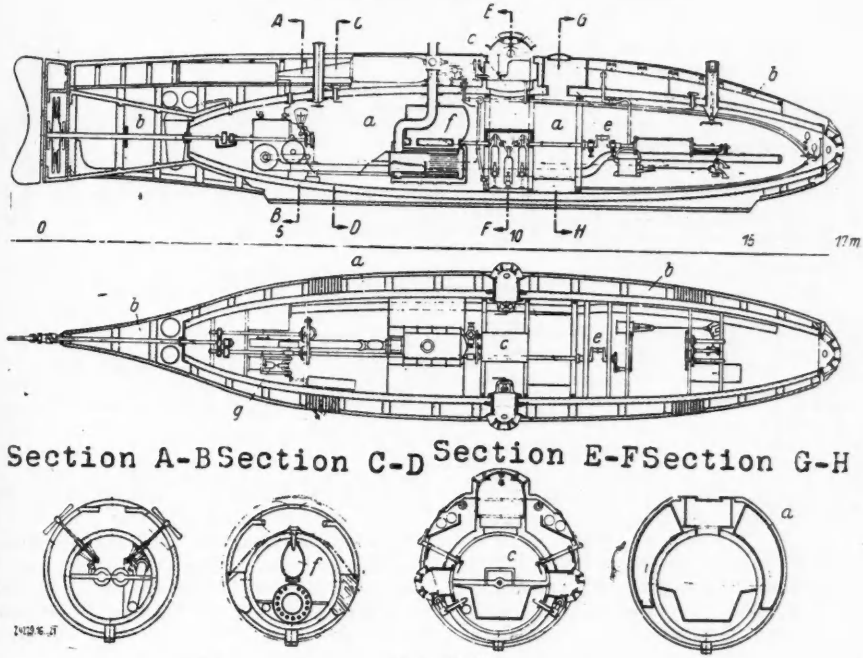


Figs. 12–13

Germany. The German Navy undertook the construction of submarines first in 1904. Encouraged by the good results obtained with an experimental boat the "Forelle" (Figs. 12-13), of 17 tons displacement equipped with two torpedo tubes, the German Navy ordered the first "U 1" submarine (Figs. 14-15). This boat was in service until 1918, and is at present in the German museum at München. The designer of this boat was D'Equevilley, and it was manufactured by the Krupp Germaniawerft, Kiel.



Figs. 14–15

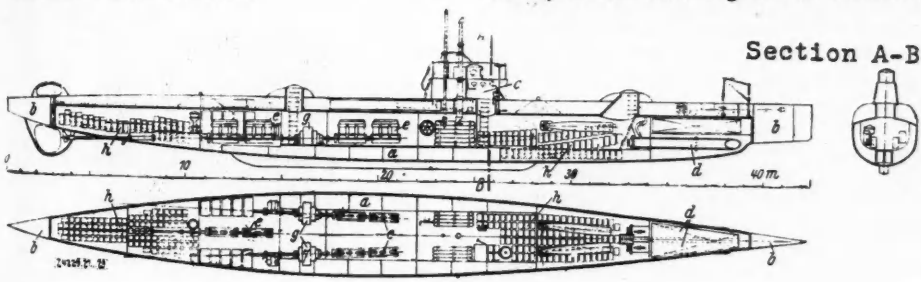


Figs. 16–21

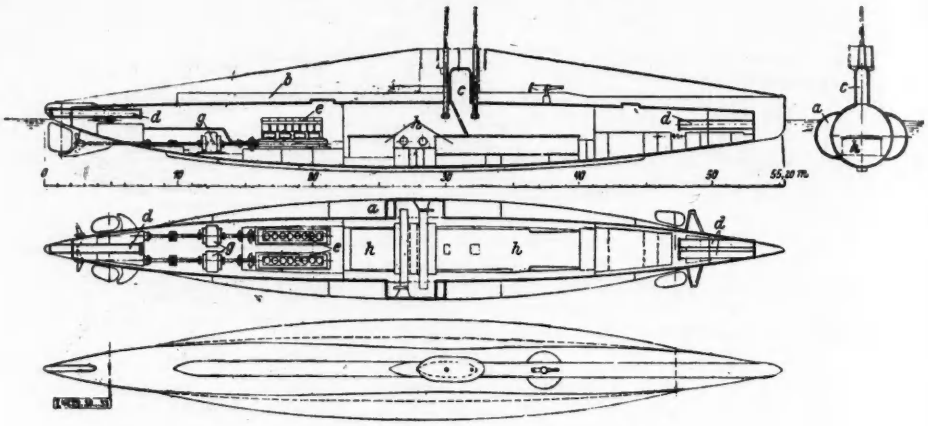
Spain. Here the first submarine was designed by Narciso Monturiol in 1862. Figs. 16 to 21 show the cross section of this boat, called "Ictineo." The steam boiler used on the surface course was also used under water, by heating it by the oxidation of chemical substances. The oxygen liberated was used for air-conditioning. The boat with a double-walled hull was of a modern shape. The diving tanks were emptied by compressed air produced by special compressors. The pumps were steam or hand driven.

Although there were only 10 to 15 years until the outbreak of the war, progress in the development of the submarine was rapid. In the U.S.A. the Diesel motor was commonly introduced. Size and output were increased. At the outbreak of the war about 30 submarines were in service, the biggest of which had 390 tons displacement. Much larger boats were under construction.

France too, possessed a large number of submarines of various types, mostly steam driven, as the Otto engine was considered



Figs. 22–24



Figs. 25–28

dangerous. At the outbreak of the war, France had about 70 boats in service fit for war purposes.

Italy was building various smaller boats designed by Laurenti. Figs. 22 to 24 show the submarine "Foca" type designed in 1905. Several of these were fitted with three Otto motors. After the explosion on the "Foca" in 1909, the Italian Navy changed over to the Diesel motors. In 1914 Italy possessed 14 U-boats, the biggest of which was 345 tons.

England had at her disposal in 1914 17 submarines of the C-class of 280 tons displacement, 8 D-boats of 550 tons, and 7 E-boats of 730 tons. Figs. 25 to 28 show an E-class boat with lateral diving tanks.

INVESTIGATION OF THE TORSIONAL RIGIDITY OF SHAFTS WITH HIRTH TOOTHING

By Dr. Ing. Gerhard Schemberger. (From "MTZ," *Motortechnische Zeitschrift*, Vol. 2, No. 10, October, 1940, pp. 328-329).

Hirth toothing for shaft coupling is quite frequently employed especially in cases where high torsional stresses are present. As shown in Fig. 1 the principle of Hirth toothing is to connect two shafts with toothing at the ends to be coupled by means of a coupling bolt. In this article the experimental determination of the torsional stiffness of a shaft with Hirth toothing will be described and the results compared with that of an ordinary shaft.

It was necessary to carry out statical experiments on the shaft. A smooth cylindrical shaft (Fig. 2), made up of seven pieces, was used. The 5 middle shaft parts, with toothing of Z = 12, 16, 24, 32, and 48 (Z = no. of teeth), were used for the experimental measurements. The torsional deflection was measured with mirrors 50 mm. apart, attached to the shaft. Between each two mirrors 1-2, 2-3, 4-5, 6-7, and 7-8 there is a toothing, and between the mirrors 3-4 and 5-6 there are only simple shaft parts for comparison. Finally a mirror (9) was attached to the

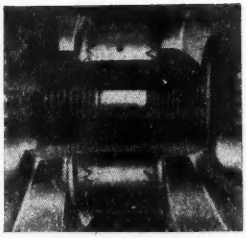


Fig. 1

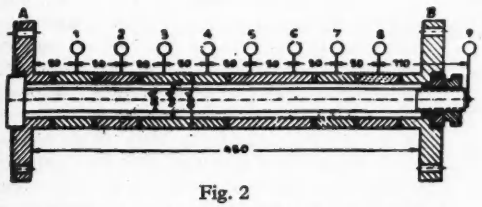


Fig. 2

coupling bolt. A pure twisting movement was applied to the shaft and the deflections were measured in the usual manner. The experiment was repeated for different values of Z and initial stress p in the shaft. The latter could be calculated from the initial stress in the coupling bolt, which could be varied by tightening or loosening the bolt on it.

The co-efficient of absolute torsional rigidity k_h is given by

$$k_h = \frac{a_h}{a_h + \Delta a_h} \quad \text{.....(1)}$$

and the co-efficient of relative torsional rigidity k_1 is given by

$$k_1 = \frac{a_1}{a_1 + \Delta a_h} \quad \text{.....(2)}$$

where a_h = angular displacement of a simple shaft of length h.

a_1 = angular displacement of a simple shaft of length 1.

h = the actual height of tooth, measured along the outer diam.

Δa_h = the additional angular dis-placement due to the toothing.

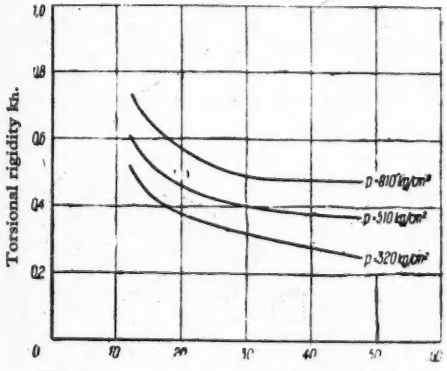


Fig. 3 Number of teeth 2·

$a_h + \Delta a_h$ = the angular displacement of a toothed shaft of length h.

$a_1 + \Delta a_h$ = the angular displacement of a toothed shaft of length 1.

a_1 and $(a_1 + \Delta a_h)$ have values obtained from the experiment.

By making $m = h/1$, and noting that $a_h = m.a_1$, then from equations 1 and 2.

$$k_1 = \frac{1}{1 + \frac{m}{k_h} - m} \quad \text{.....(3)}$$

As the experimental results in Figs. 3-5 are expressed in terms of k_h, k_1 can be calculated from equation 3.

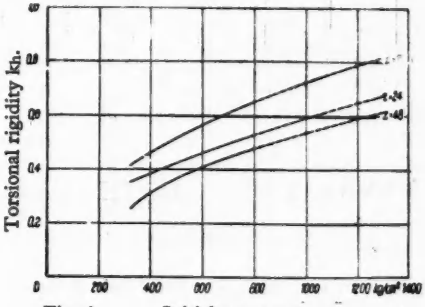


Fig. 4 Initial stress p.

Results.

Fig. 3 gives values of k_h of a Cr.-Ni-steel shaft, dependent on the number of teeth Z, for three different values of p. Fig. 4 gives values of k_h for various values of p, with Z = 16, 24, and 48. Fig. 5 gives results for an electron shaft dependent of Z, when p = 700 kg/cm².

It can be seen that if p is large, k_h is decreasing rapidly until Z = 24, and decreases more slowly afterwards.

With increasing value of p, k_h is increasing and is approaching a limiting value less than unity. The value of p during the experiment could not be made to exceed p= 810 kg/cm². With increasing initial stress the influence of the Hirth toothing is diminishing and the shaft characteristics are approaching that of an ordinary shaft.

With new methods it is quite easy to obtain stresses of p = 1200 kg/cm² and over. At

this value of p, with Z = 48, it can be predicted that k_h will be equal to 0.6, with Z = 24, k_h = 0.66, and with Z = 16, k_h = 0.79.

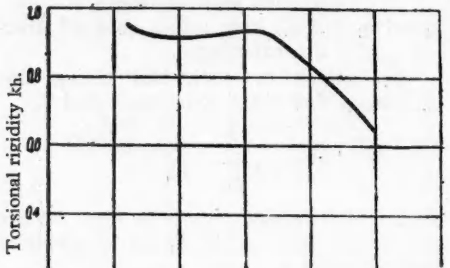


Fig. 5

In case of the electron shaft, i.e., soft material, the resulting graph is at a considerably higher position and at Z = 32, k_h reaches 0.95, and is decreasing from this point on. The different behaviour of various materials will not be discussed here, but it can be stated that in general a material with small transverse modulus has a smaller additional angular displacement a_h due to toothing, than one with a higher modulus. Hence the softer the shaft material, the more advantageous it is to use Hirth toothing.

Care was taken during the experiment to ensure that the coupling bolt shall undergo the same torsional displacement as the shaft. The stiffness of the coupling bolt was subtracted from the results to obtain values of k_h for the shaft only. In practice this condition will not be fulfilled, with the result that the values of k_h will be higher still.

TANKS USING BOTH CATERPILLAR AND WHEEL DRIVES

(From *Zeitschrift des V.D.I.*, Berlin, January, 1941).

ALTHOUGH a combined wheel and caterpillar drive for fighting vehicles has certain disadvantages it has often been tried with more or less success. A fairly remarkable solution of the problem is shown in Figs. 1 to 3. The Swedish fighting vehicle "Landsverk," uses ordinary disc wheels with tires for driving on the road at a speed of 78 km/h, whereas over pathless fields it reaches 36.8 km/h with lifted wheels using the caterpillar treads only (Figs. 2 and 3). The water cooled 12-cylinder motor, type Maybach, has an output of 180 Hp, and may be overloaded to 200 Hp. The action radius on the road is 300 km. The fighting vehicle has two motions, one for the front wheels and the other by means of a sun and planet motion when using the caterpillar. The total weight is stated to be 11.6 tons. The armament consists of one 4.7 cm. gun and two light water cooled machine guns.

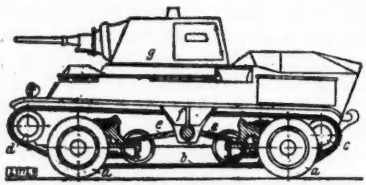
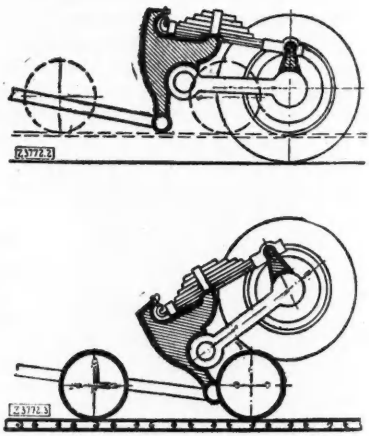


Fig. 1



Figs. 2 and 3

AERODYNAMICS AND AERONAUTICS

By P. FABER. (From *Brown Boveri Mitteilungen*, Vol. 27, No. 1, Jan., 1940, pp. 20-24).

BROWN BOVERI & CIE, Baden, calling on their vast and varied experience in the construction and design of turbines, compressors, and pumps, have recently extended their field of activities by the construction of wind tunnels. Such a plant has been completed for aerodynamic experiments on air-screws, aerofoils, projectiles, etc., at the Technical High School, Zürich.

The wind tunnel is part of a closed circuit containing the turbo compressor (1), the air cooler (2), the streamlined model section (3), and the eduction branch (4). The induced turbulent effects on the air stream by the three right angled bends is minimised by using suitable guide blades, contained in a grid placed across the section. A vacuum pump is employed to create a partial vacuum in the tunnel thereby reducing the driving power to within reasonable limits. The blower of the wind tunnel has an output of 55 m^3/sec. at a pressure of between 0.125 to 0.275 kg/cm^2 abs. working at a speed of 3400 r.p.m. The speed can be increased up to 3800 r.p.m., which makes it possible to reach double the velocity of sound or 2300 km/h. in the model section. The compressor is driven by a 1000 kw c.c. motor through gearing (7). The speed of the compressor can be adjusted between the limits of 1000 and 3800 r.p.m.

The heat induced to the air is absorbed by an air cooler, reducing the temperature of the air from 120° C. to 45° C. The air cooler (Fig. 2) consists of two sections. In the main heat absorber there are ribbed radiator tubes, and in the second half, an oven type is provided to direct the air current into a parallel flow.

The model section (Fig. 3) consists of a converging-diverging nozzle to produce the ultra-sound velocity, and a diffusor, in which

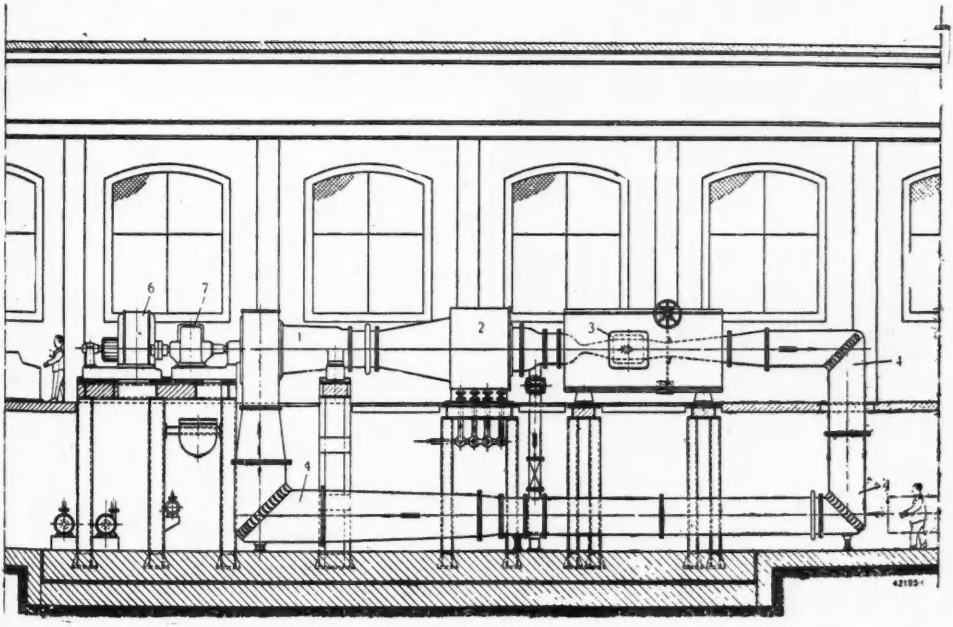


Fig. 1

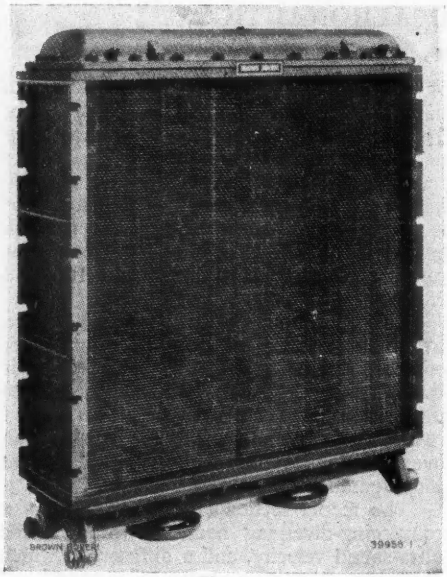
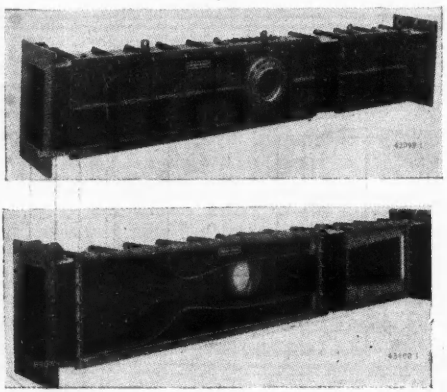


Fig. 2



Figs. 3a and 3b

the kinetic energy of the air is reconverted to pressure energy. The variation of pressure along this ultra-sound wind tunnel is shown in Fig. 4, as a function of different air velocities. It can be seen that the diffusor has an efficiency of about 60 to 70%.

In the ultra-velocity part of the diffusor the flow is very variable, and even the smallest deviation from the correct dimensions, pressure or temperature causes disturbances in the flow and fluctuations of the pressure. For this reason the tunnel and the model section are built in square section between parallel walls, for accessibility. It has been suggested to employ an adjustable model section, the dimensions of which can be altered during the experiment; the energy required for such wind tunnel is very high, however. The designer, Dr. Ackeret, estimated the required output for 700 km/h. air velocity with 4.5 m. model section as about 25.000 H.P. For such high outputs he proposes to use steam turbines with a Velox steam generator, in place of the c.c. motor.

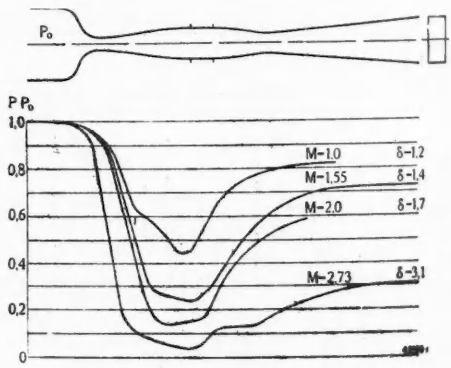


Fig. 4

FRIGIBLOC A COMPACT REFRIGERATION UNIT

By R. GILLY. (From *Brown Boveri Mitteilungen*, Vol. 27, December, 1940).

THE Frigibloc, Brown Boveri's refrigeration unit, consists of the compressor, motor, condenser, evaporator and auxiliary machinery enclosed in a gas tight casing (Fig. 1). The result of this arrangement is that the stuffing box on the compressor does not project, and so the escape of gas into the surrounding atmosphere is prevented.

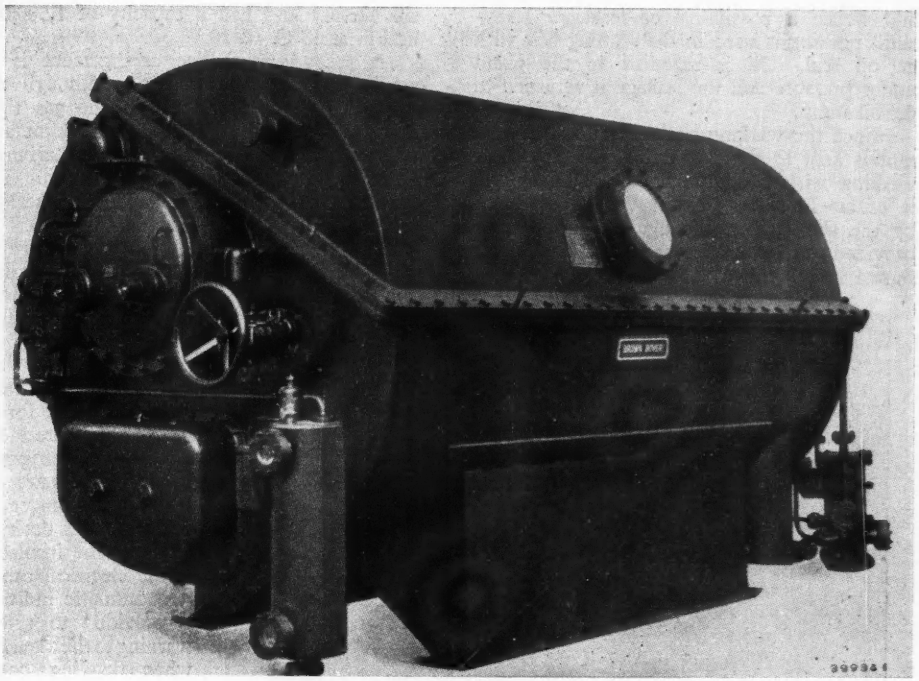
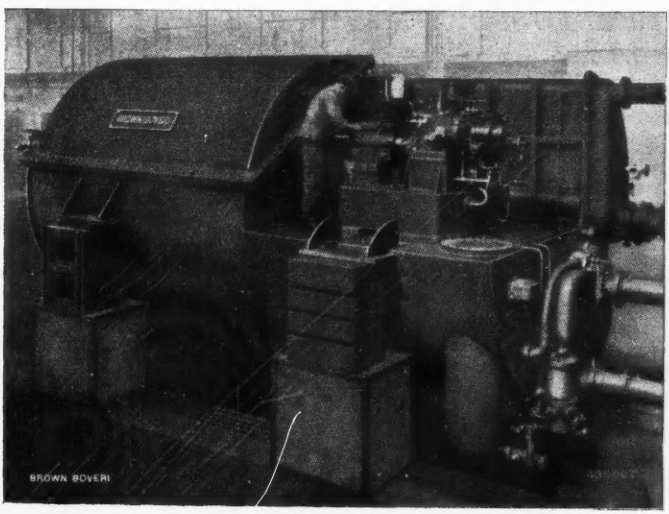


Fig. 1



The standard unit is able to absorb 25,000 to 2,500,000 kcal/h. and is motor driven. In factories using process steam, an alternative to the motor drive is a steam turbine driving a turbo compressor (Fig. 2). This arrangement allows a more flexible speed regulation, and, therefore, reduces operative losses. The disadvantage of this installation is that the turbine has to be placed outside the casing, necessitating a stuffing box,

Fig. 2. Brown Boveri Frigibloc. Output 1,500,000 kcal/h, Prime mover : Steam turbine.

and hence a possibility of leakage. Labyrinth packing is used in the stuffing box with an oil seal. Oil is supplied to the gland under pressure and the leakage is returned to the oil sump.

Since the working pressure of the refrigerant is kept to the evaporator, the condenser working with a slight vacuum, any leakage is of air into the casing. This is detected by the shell pressure gauge and a pump is provided to exhaust the air. The plant shown in Fig. 2 was delivered to an artificial silk factory and had a capacity of 1,500,000 kcal/h. at 13°C.

A second alternative arrangement is to employ a c.c. motor drive. Although the motor could be contained in the gas tight shell, the maintenance of the commutator and brushes necessitated a similar arrangement to the turbine drive installation. The plant shown in Fig. 3 rated at 320,000 kcal/hr. was delivered to a brewery.

Diesel or petrol prime movers may be specified, in which case electrical transmission, or belt drive is used. The frigibloc has automatic apparatus for removing water absorbed by the refrigerant, and also for removing moisture in the air. The refrigerant being free of water, obviates the danger of corrosion and deterioration of the insulation of the electrical cables. An automatic indicator is provided to give a warning to the attendant when flooding occurs through a burst tube.

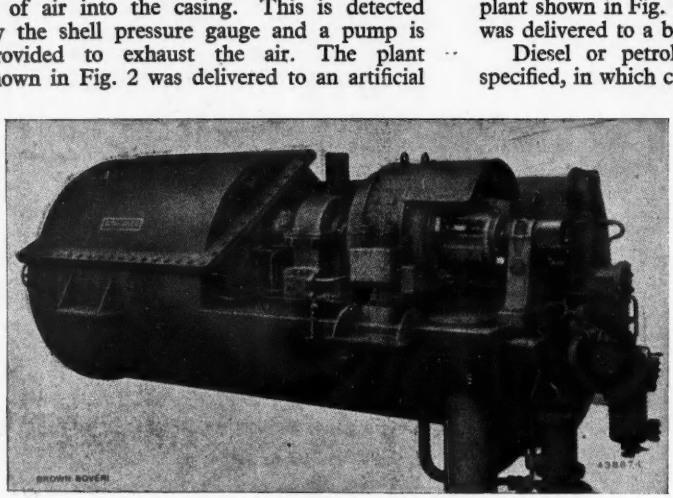


Fig. 3

NEW FOUNDRY MACHINERY

By U. LOHSE. (From *Zeitschrift des V.D.I.*, 1940).

THE progress in recent years of foundry machinery could be characterised as adaptation to the particular technique and layout of individual foundries. A few types may be taken to illustrate this phase of modern development; the introduction of new ideas rather than the modification of accepted practice.

Messrs. H. Herring, Schwelm, have evolved a new type of sand dressing machine, listed as the Samum (Fig. 1). It is in effect a centrifugal pump. The rotor is placed for ease in a horizontal position, and when revolving at its normal speed of 3000 r.p.m., draws the sand from a hopper and throws the sand against the casing.

The sifting and aerating action is increased as friction causes the sand to be thoroughly scoured in the annular ring between the rotor and the casing.

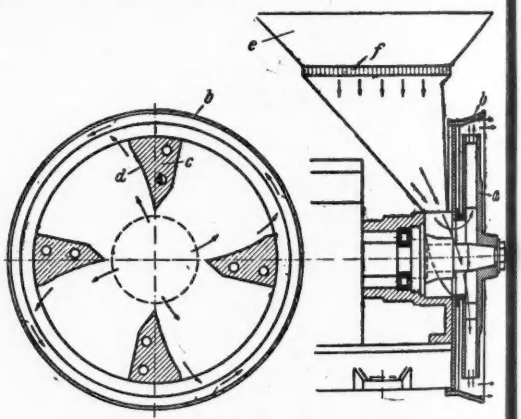


Fig. 1
Sand Dressing Machine: (a) Rotor; (b) Casing; (c) Jaw; (e) Hopper; (f) Sieve.

Most of the new mould filling machines employ compressed air. By vibration of the mould, the sand around the pattern is consolidated and finally compressed by direct pressure. In this way even complicated patterns can be moulded. A filling plant constructed by Badische Maschinenfabrik is shown in Fig. 2. Under the two sand bins are arranged two vibrating tables, powered by compressed air. The half moulds are placed on these tables. A roller conveyor connects the two tables and also to the foundry; in this way the two half moulds are removed from the filling table, placed in position on the conveyor and brought to the foundry.

The sand from the used moulds is returned to the sand dressing plant by an underground conveyor. In Fig. 2 the sand from the moulds is tipped into a hopper, into which is discharged a measured quantity of coal dust. A bucket elevator transports the sand to a centrifugal sand mixer, where it is thoroughly mixed and aerated. The dressed sand is transported to the sand bins by a belt conveyor: a conveyor is also employed to fill the moulds with sand from these bins. With this particular plant 8 men are able to fill 67 large moulds in 8 hours.

A. G. der Eisen und Stahlwerke, Singen-Hohentwiel, have manufactured a new mould

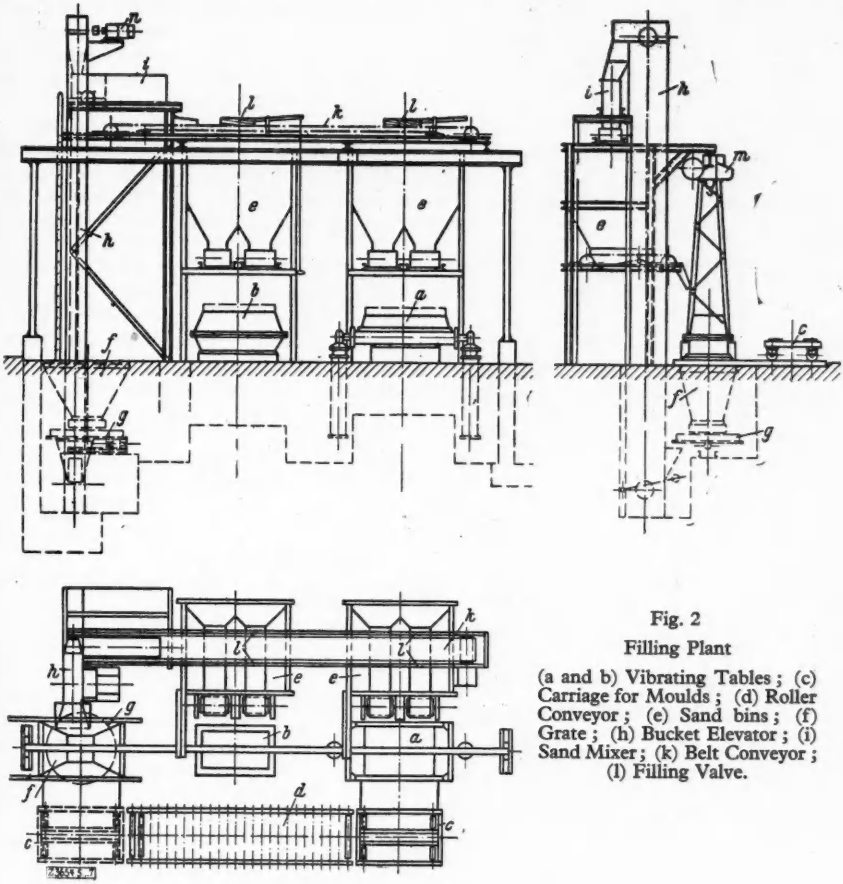


Fig. 2

Filling Plant

(a and b) Vibrating Tables; (c) Carriage for Moulds; (d) Roller Conveyor; (e) Sand bins; (f) Grate; (h) Bucket Elevator; (i) Sand Mixer; (k) Belt Conveyor; (l) Filling Valve.

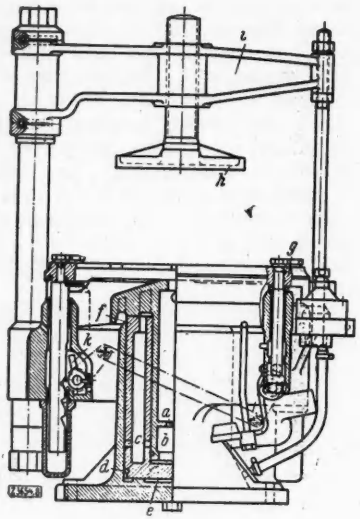


Fig. 3
"Nichols Press" Mould Filling Machine.

filling machine, the "Nicholls press (Fig. 3). In this machine, both vibration and direct application of pressure is employed to consolidate the sand. One valve only is utilised to control the operations of the press. The table on which the mould rests is secured to the vibrating piston (a) working in the hollow ram (f), which acts as the bed of the machine. Compressed air under the piston (b) forces the table to rise until the pressure is releaved by the opening of parts (c). The desired vibration is caused by the impact when the piston returns to the initial position. Finally the sand is pressed home in the mould by admitting compressed air to the space below the ram, forcing the mould against an anvil (h). Disengaging the racket (k) allows the table to sink under its own weight. Efficient means of cylinder lubrication is provided to ensure ease of operation.

The newest type of core blower, manufactured by Albertus Werke, Hannover-Hainholz, is outlined in Fig. 4. Compressed air is led to the fixed cylinder (b), through the operator's control valve (a) and causes the ram (c) to move outwards. The barrel (e) is filled with sand from the drum (f). The drum (f) can be rotated only when the barrel (e) is clear, as it is separated by a servo-motor working in conjunction with the main ram. Air is supplied to the servo-motor piston only when the ram is in the initial position. The ram may be returned to this position by leading air to the cylinder (d) through the operator's control valve.

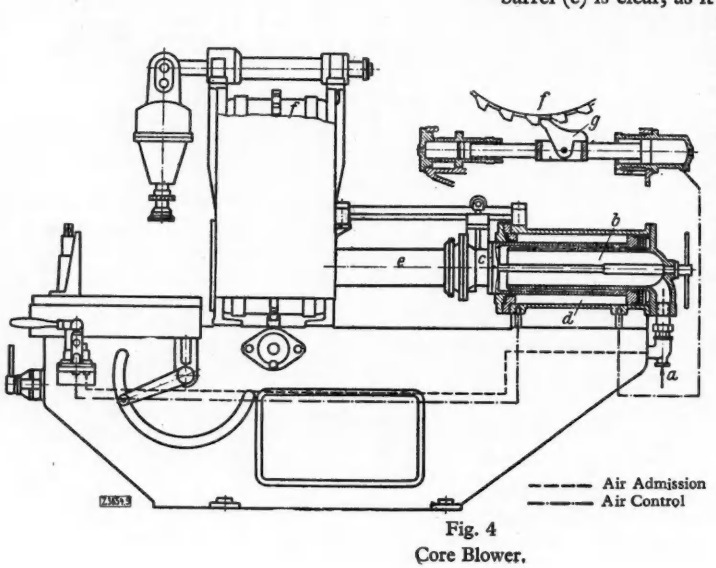


Fig. 4
Core Blower.

THE EVOLUTION OF THE BOILER

By OBERING K. SCHRODER. (From Siemens' *Zeitschrift*, December, 1940)

THE beginning of boiler history is defined by the "drum only" boiler, and the present by the "tube only" generator. Between the two the many and varied designs may be classified into five orders, viz.

(1) Tank boilers with external firing.
(2) Cylindrical boilers with internal firing.
(3) Water tube boilers with natural circulation.
(4) Tubular boilers with a steam drum, employing forced circulation.
(5) Tubular boilers with forced circulation and no steam drum.

The first boiler ever to be used for industrial purposes was merely a suitable reservoir (Fig. 1) placed over a banked fire, and generating steam at atmospheric pressure, or at the most, at a pressure of 0.3 kg/cm². As the demand for higher outputs and efficiencies increased, two or more boilers were placed over the furnace, so that a greater proportion of the heat was utilized.

Considerable progress was then made by the introduction of the annular boiler (Fig. 2). The flue gases were allowed to sweep through the centre of the boiler, and thus the effective heating surface was doubled. This marks the first stage in the progress to higher output per boiler weight figures.

The high outputs demanded by the world's navies and by municipal power stations led to the development of the water tube boiler, employing natural circulation. The progress from the fire tube boiler to the water tube boiler was decisive, enabling steam generation on a scale never before envisualized. The water tube boiler developed along parallel lines, either employing horizontal or vertical banks of tubes and, at the beginning of this century, were fitted with economisers and steam superheaters. This marks a new epoch in the construction of boilers. Up to this moment the movement of the steam and water was due to the thermo-syphon action in the differentially heated water tubes. In economiser and superheater sections, however, heat was absorbed under forced circulation conditions; the evaporation of the water, however, still proceeded under conditions of natural circulation. From now on, the heating surface in the section employing forced circulation became greater, while that using natural circulation was reduced. Feed heating and superheating were developed, and part of the function of the heating surface using natural circulation was transferred to the economiser, increasing the surface employing forced circulation. For high pressures an intermediate superheater had to be provided, and to-day only a small proportion of the heating surface is placed before the superheater; in fact, some of the modern boiler installations have eliminated heating elements employing natural circulation, and

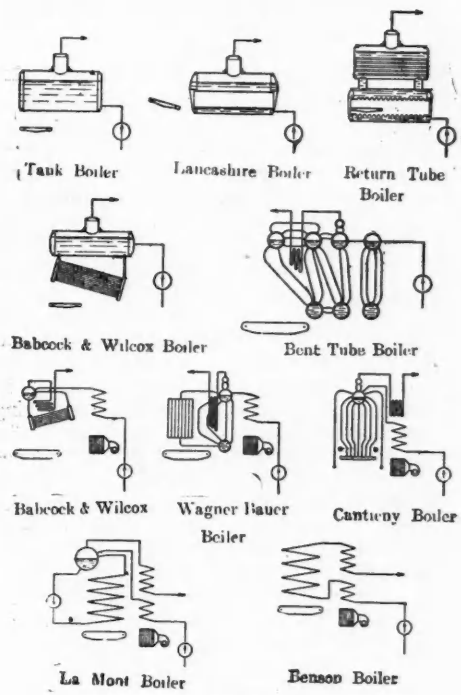


Fig. 1

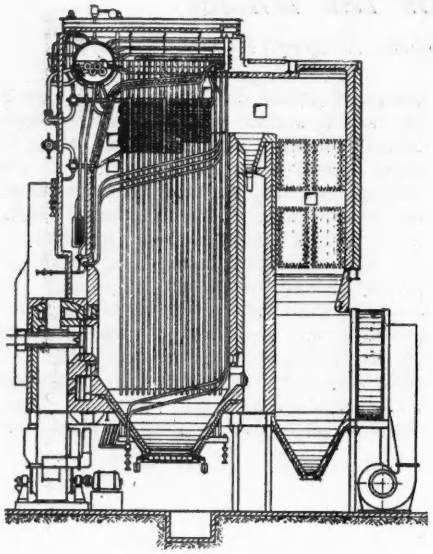


Fig 2.

the boiler operates with forced circulation only.

The modern water tube boiler differs considerably from the vertical or horizontal tube boiler of 10 to 30 years ago. Instead of a multiplicity of drums, one or two drums at the most are used only, the proportion of the heating surface given to natural circulation has been reduced from 50 to 100% to 5 to 25% of the total heating surface. The high outputs of modern boilers have emphasised the need for positive and certain water circulation, and great care has to be taken in the tube arrangement that no disturbing influence on the circulation can occur. The circulation in these boilers is due to thermo-syphon effects, the differential heating of the tube bank causing water to rise in the tubes nearer to the furnace and to sink in those tubes removed from the furnace. In contrast with the earlier types of boiler the steam is generated in the tubes, the steam drum merely acting as a reservoir for the feed water, and steam. The greater part of the feed water does not circulate more than once over the heating surface.

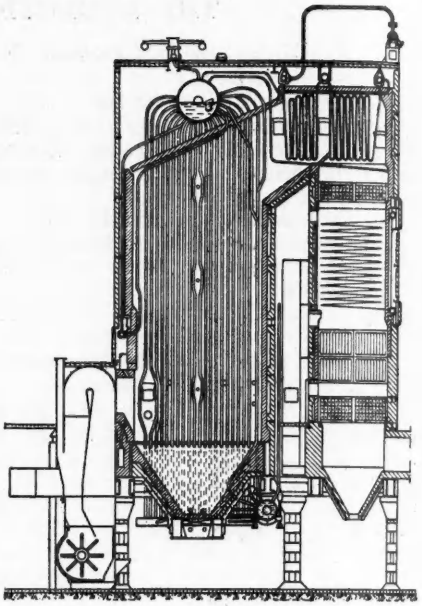


Fig. 3

When it became apparent that natural circulation would be insufficient for the high forcing rates proposed, forced circulation was employed. The results of forced circulation are twofold: the turbulent flow of the water allows of a high absorption of heat by the disturbing blanketing effect of the steam film on the tubes, and it allows the height of the boiler, necessarily high to maintain natural circulation, to be reduced. Evaporation and separation of steam from feed water is the same as for the natural circulation group of boilers.

In the first instance these boilers employed one drum, which acted as a reservoir from which the circulating pump took its suction. With the accumulation of expeperience, steam generators were constructed without a steam drum, with the advantages of economy, lightness, and simplicity. The last stage in boiler development was reached with the elimination of the steam drum, and now flask boilers are well established. Benson pioneered this development and Sulzer, Ramsin, Doble, have manufactured reliable

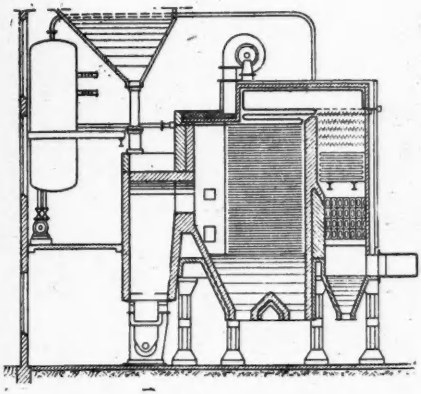


Fig. 4

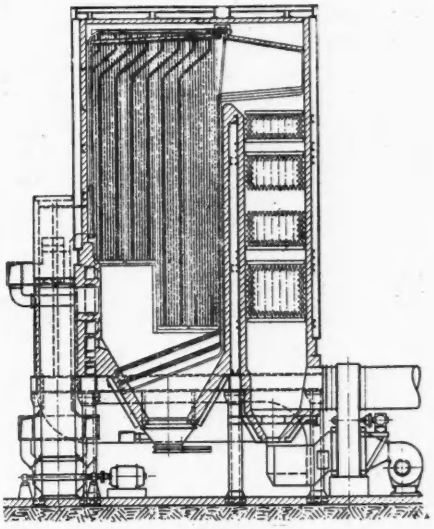


Fig. 5

generators since. In this type of boiler, evaporation is controlled completely by the operation of the circulating pump.

The distinction between modern boilers operating either with natural, forced circulation or forced filtration is in the evaporating element. Four of the newest boiler types are shown, and for better comparison boilers have been chosen which employ mill furnaces.

Fig. 2 shows a natural circulation generator developed from the vertical water tube boiler. A greater part of the heating element is under forced circulation, only the radiation heating surface and three rows of water tubes directly absorbing heat, employing natural circulation.

Fig. 3 shows a similar type of boiler where only the radiation heating surfaces utilize natural circulation.

In Fig. 4 the La Mont generator is provided with one drum outside the boiler, and forced circulation is arranged for the whole heat absorbing surface.

Finally, in Fig. 5 a Benson boiler is shown which has no drums, and is entirely dependent on forced circulation.

THE NEW SIEMENS BOILER REGULATOR

(From Siemens' *Zeitschrift*, Vol. 21, No. 1, Jan.-Feb., 1941, pp. 32-34).

THE new automatic boiler regulator developed by Messrs. Siemens & Halske, is based on electric control of the fuel and air supply, so as to adapt the boiler output to the actual steam demand. The system offers many advantages, not the least of which is the simple arrangement of the electrical circuits, and the possibility of remote control in place of the automatic regulation.

It is essential that regulation should proceed gradually. The effect of a small change in the regulation should bring about the required effect before the next adjustment is necessary. Naturally, the duration of the individual regulation steps will vary with the type of boiler, furnace, storing capacity, furnace sluggishness, etc.

The fuel supply is controlled by the current required by the a.c. motor driving the moving grate. Air regulation is by control of the fans, and the air pressure inside the boiler is kept constant by suitable regula-

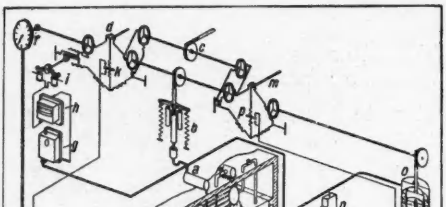


Fig. 1

Scheme of the Installation of a Siemens Regulator for a Boiler Plant: (a) Steam collector; (b) Stop valve; (c) Regulator for fixed load; (d) Load regulator; (e) Motor; (f) Tachometer; (g) CO_2 indicator; (h) CO_2 regulator; (i) Fuel/air regulator; (k) Relais; (l) Motor and shunt regulator.

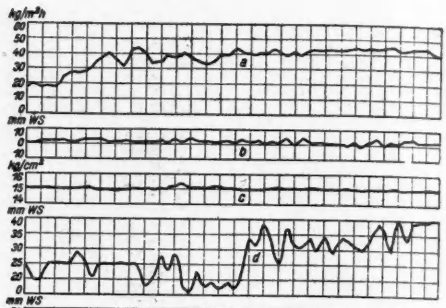


Fig. 2

(a) Steam output; (b) Pressure in fire box; (c) Boiler pressure; (d) Induced draught; (e) Forced draught; (f) Fuel consumption; (g) CO_2 regulator operates; (h) CO_2 content.

tion of the exhaust fans. The air/fuel ratio is governed by the CO_2 content of the exhaust gases. An increasing CO_2 content means that combustion is taking place near the end of the grate, and, therefore, the grate speed has to be reduced.

The efficiency of the regulation can be studied from Fig. 2, showing that the boiler pressure, air pressure, CO_2 content remains almost constant even with varying load.

Boilers which respond slowly to adjustment should be fitted with special regulators to avoid over-regulation and oscillation of pressure. For this purpose an elastic return is used, in which a resistance fitted in a regulator should adjust the tachometer or air venturi-meter to equilibrium position before the theoretically correct value is obtained by the regulator. When the boiler output is approaching the value corresponding to the load, this primary adjustment vanishes.

Very satisfactory results were obtained with a boiler using coal dust, although the lower limits of regulation could not be extended very far owing to the ignition temperature of the fuel air mixture.

The regulation follows changes of about 2% of the CO_2 content. It is claimed that with variation of the load of about 80% the steam pressure was kept at 15 atm. within $\pm$ 0.05 atm. pr., compared with hand regulation where $\pm$ 2 atm. pressure variations are not unusual.

IRREGULAR WEAR OF MOTOR CAR TYRES

By H. P. Zoeppritz. (From *Zeitschrift des V.D.I.*, June, 1940).

Automobile tyres are subject to irregular wear, in which one side of the tread is worn away, while the other side shows no sign of deterioration. Investigations on the cause of this phenomenon were made on wheels of cars, and also on suitable models. As this type of wear was first discovered on the tyres of cars using the Reichsautobahn, the road surface itself and the manner of driving on the road, was thought to be responsible. At a later date the tyres of cars not using the autobahn exhibited this irrational wear. An-

other point of interest was the fact that only the tyres on trailing wheels were subject to "wavy wear," viz., the front wheels of normal drive automobiles and motor cycles and the rear wheels of front-drive automobiles. This knowledge paved the way for a systematic examination of the factors influencing tyre wear, and it was firmly established that irregular tyre wear was in no way dependent on (a) the type of axle, whether floating or rigid (b) front or back drive (c) type of suspension (d) want of dynamic balance of the type; the experimental tyres showed signs of wear in spite of most careful balance (e) vibration of the wheel.

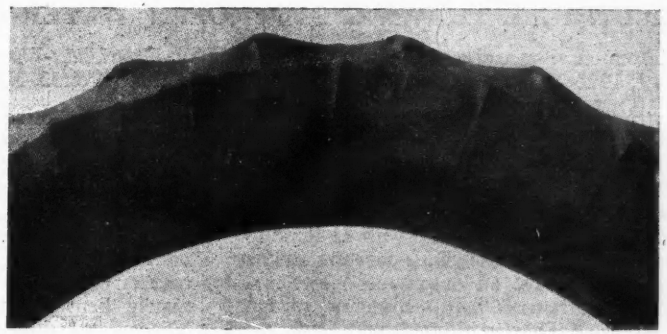


Fig. 1 Wavy wear of tyre.

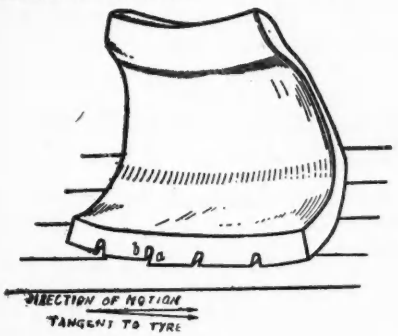


Fig. 2
Friction of tyre when leaving surface of contact: (a) Forward pressure on tyre; (b) Pulled back after leaving surface of contact.

The inherent cause of irregular wear was established as relative movement between tyre and road influenced by the position of the wheel, pressure on the tyres, and profile of the tyre. In the light of this knowledge, all the factors affecting wear were examined on experimental model and on actual tyres in use. The research confirmed the general conclusion made on tyre wear and indicated by what methods it could be reduced. It was found that the factors influencing tyre wear are:

(1) Shearing forces between the tyre and roadway due to slip of the trailing wheels of the automobile. There is a critical shear stress, which, if exceeded, results in a rapid but nevertheless a uniform wear. A good road surface as the automobilbahn causes excessive wear, as the slip is more pronounced.

(2) The profile, certain profiles being more resistant to tyre wear than others.

(3) Position of the wheel, which influences the run of the tyre at the area of contact with the road, and which may induce excessive shear stresses in the tread of the tyre.

(4) The normal pressure between the tyre and road. The normal pressure causes a distortion of the tyre, and therefore a second system of shear forces in the tyre crown is induced. Faulty shock absorbers also influence tyre wear, as the wheel vibrations aggravate the distortions of the tyre.

The investigations clearly showed that to reduce tyre wear, attention must be paid to the tyre profile, spring suspension, and rotation of the wheels.

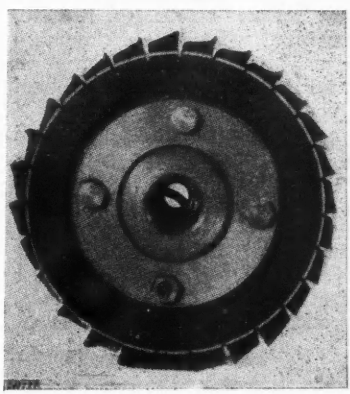


Fig. 3
Wear on model tyre with 10 mm. tyre crown after 9,000 km.

ELECTRICAL THAWING OF FROZEN WATER PIPES IN BERLIN

(From an abstact of a publication of R. Kalicinsky, *Elektrizitäts-Wirtschaft*, Berlin, Vol. 41, No. 1, 1941; in *Bulletin of Association des Electriciens Suisse*, Vol. 32, No. 1, Jan. 15th, 1941, p. 12.)

WATER mains of 6200 houses, 250 pipes in the distribution system, and 150 pipes in buildings have been thawed in Berlin between 5th January and 15th April, 1940, by the Water Works and some plumbers. This work has been accomplished with 31 thawing transformers and one D.C.-converter. The transformers have an output of 6 kw. (secondary current 300 A, secondary voltage 10-20 V.). They are fitted with switches and fuses on portable frames which are brought to the working place by car. For small pipes inside buildings smaller transformers with an output of 1 kw. or more are used. The machine set used in the D.C.-distribution district consisted of a D.C.-motor of 8 kw. and a generator for 24 V. and 400 A. This set was assembled with a switchboard in a small trailer.

The transformers or the converter were connected by erectors of the Berlin Electricity Works to the house main or to another point of the distributing main. No meters were used, the consumption of energy being reckoned in a lump sum.

The time needed to thaw a pipe depends on the resistance of the pipe, which depends on the length, diameter and laying of the pipe, and on the pipe unions used. The time necessary for the thawing varies approximately between 10 minutes and 3 hours. The average time needed for a house main of a length of 20 m. laid in the soil was about 1 hour. For similar pipes in the D.C.-current district 2 hours were needed. The average for all 6600 thawing operations in Berlin was approximately 2 hours. The average energy consumption for one thawing was 6 kwh.

Only 2% of the operations were unsuccessful. These were cases where rubber gaskets had been used or cement-asbestos pipes without metal connections.

SODIUM ALUMINATE AND ATMOSPHERIC EFFECTS ON PROPERTIES OF A FLINT CLAY REFRACTORY

(From *Technical News Bulletin of the National Bureau of Standards*, Washington, No. 286, February, 1941, p. 18.)

IN this investigation, three refractory mixes were studied. Mix A contained 93.55 per cent. of Kentucky flint clay and 6.45 per cent. of Tyrone plastic clay. The flint clay portion consisted of 55 per cent. which passed the No. 4 and was retained on the No. 10 sieve, and 38.55 per cent. which passed through a No. 100 sieve. Mix B differed from A in that it contained 0.75 per cent. of sodium aluminate ($Na_2O.Al_2O_3$). (SiO_2). Mix F differed from B in that the flint-clay portion consisted of 20 per cent. which passed the No. 4 and was retained on the No. 10 sieve, and 73 per cent. which passed through a No. 20.

Specimens of each of these three mixes were heated to 1,400° C. under oxidizing conditions for 25 hours and for 105 hours, and under reducing conditions for 105 hours. Determinations of the CO_2 content were made during each burn for purposes of atmosphere control within the furnace.

The results of tests of five specimens showed: (1) The modulus of elasticity and strength were much lower for specimens heated 25 hours (oxidizing) than when they were heated for 105 hours in either a reducing or an oxidizing atmosphere; (2) the sodium aluminate caused the modulus of elasticity and strength of the specimens to be greatly decreased regardless of atmospheric conditions; (3) the sodium aluminate also caused the extensibility of the specimens to be greatly increased; and (4) the specimens heated for 105 hours under reducing conditions showed both greater strength and modulus of elasticity than did those heated in an oxidizing atmosphere for a similar period of time.

CORROSION PITTING OF ALUMINIUM BRONZE AND MONEL METAL IN WATER

(From *Technical News Bulletin of the National Bureau of Standards*, Washington, No. 286, February, 1941, pp. 15-16.)

THE influence of stress on the corrosion pitting of aluminium bronze and monel metal under water has been investigated by D. J. McAdam, Jr., and Glen W. Geil.

Corrosion pits in steel are free to assume a roughly hemispherical form. This is also true of monel metal, but is not the case with aluminium bronze, because the pits are confined between crystallites of the alpha phase. Pits in aluminium bronze and monel metal are much smaller than those in steel, but cyclic stress tends to increase both their size and sharpness, a sufficiently high combination of stress, cycle frequency, and corrosion time causing fissures to develop from blunt pits. Fissures in aluminum bronze generally are oblique, whereas those in steel and monel metal tend to be perpendicular to the direction of the principal tensile stress.

The effective stress concentration that causes the lowering of the fatigue limit depends on the size and sharpness of the pits. The curves of decrease of the fatigue limit with corrosion time are of the "accelerated damage" type, and are obtained when the corrosion rate is anodically controlled. With these two alloys, therefore, the pits in a specimen have a wider range of size and sharpness than the pits formed under cathodic control, as in steel. The pit that caused the lowering of the fatigue limit sometimes is much larger and sharper than the pits found in the sectional views and, for this reason, the damage may be greater than the sectional views would indicate. Many of these views, however, give good correlation with the resultant fatigue limits.

Steady stress tends to accelerate corrosion of aluminium bronze, but steady stress of any attainable value has no apparent effect on the corrosion pitting of monel metal.

SPOT WELDER WITH MAGNETIC STORAGE

(From *Electrical World*, Vol. 115, No. 4, January 25th, 1941, pp. 314-315).

FUNDAMENTAL principle underlying operation of a new spot welder for Aluminium introduced by the Sciaky Corporation, Chicago, involves the storage of energy in an iron-core-transformer-reactor, and the release of that energy as an instantaneous heavy current surge in the low-resistance secondary welding circuit.

A 40 kVA three-phase transformer feeds a mercury arc-rectifier (Fig. 1), which supplies D.C. current at 110 v. to the primary winding of a transformer-reactor. The degree of saturation of the core attained depends on the

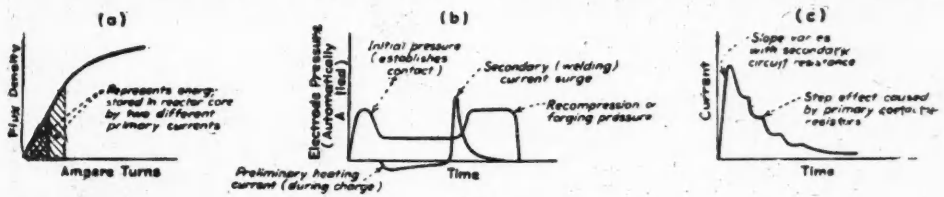


Fig. 2.

Operational aspects of the Sciaky welding system.

(a) Energy stored in iron core of transformer reactor, proportional to area under magnetisation curve, is released in secondary circuit to do welding work.
(b) Typical welding cycle shows variation of electrode pressure and current in welding circuit. Small current flow during charging of reactor and heavy welding surge on release.
(c) Time control of welding surge is obtained by variation of secondary resistance. Current decay is determined by fixed resistance steps in reactor primary circuit.

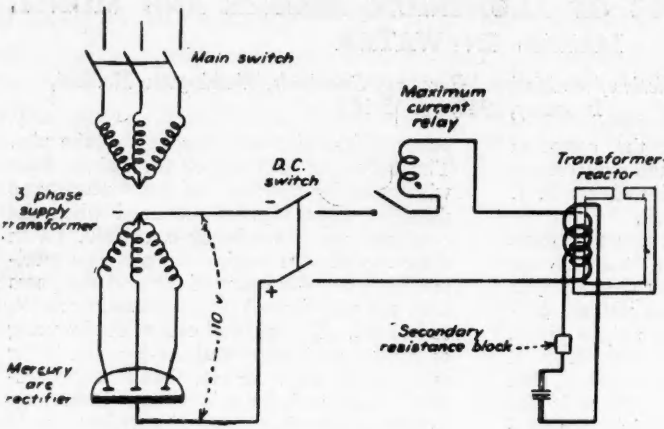


Fig. 1.

Transformer reactor is charged from 3-phase mercury arc-rectifier. Adjustable current relay opens primary circuit at any pre-selected current value.

setting of a maximum current relay in the primary circuit, which can be adjusted to open this circuit at any value of the primary current up to 400 A. It is set for the value of primary current and consequently for the degree of saturation of the core, which corresponds to the value of stored energy necessary for welding the gauge of metal in hand (Fig. 2). When this value of current is reached the relay trips and the primary circuit is opened. The magnetic energy stored in the core is dissipated by the current induced by the decaying flux in the low resistance of the secondary circuit. In order to control the decay of secondary current, four resistors in decreasing steps are connected across the primary switch by four contactors operating successively over a very short space of time after the maximum current relay operates.

During building up of the primary current and of the core saturation a small current is induced in the secondary circuit, which has the desirable effect of slightly preheating the material. The time, during which the welding current flows, can be adjusted according to the gauge of the material to be welded by inserting resistance blocks of different sizes in the secondary circuit.

It is claimed by the manufacturers that a 40 kVA Sciaky welder will perform the same welding duty as a 400 kVA conventional single phase A1-welder and that flicker is proportionally reduced. Sciaky welders are capable of 40-60 welds per minute. The load of these welders is balanced, whereas an equivalent single-phase welder represents an extremely unbalanced load.

Fig. 3 shows a Sciaky welder in operation.

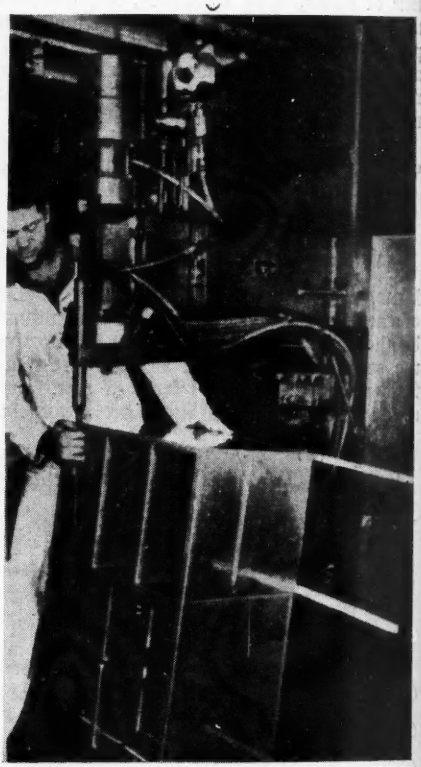


Fig. 3 Sciaky welder in operation.